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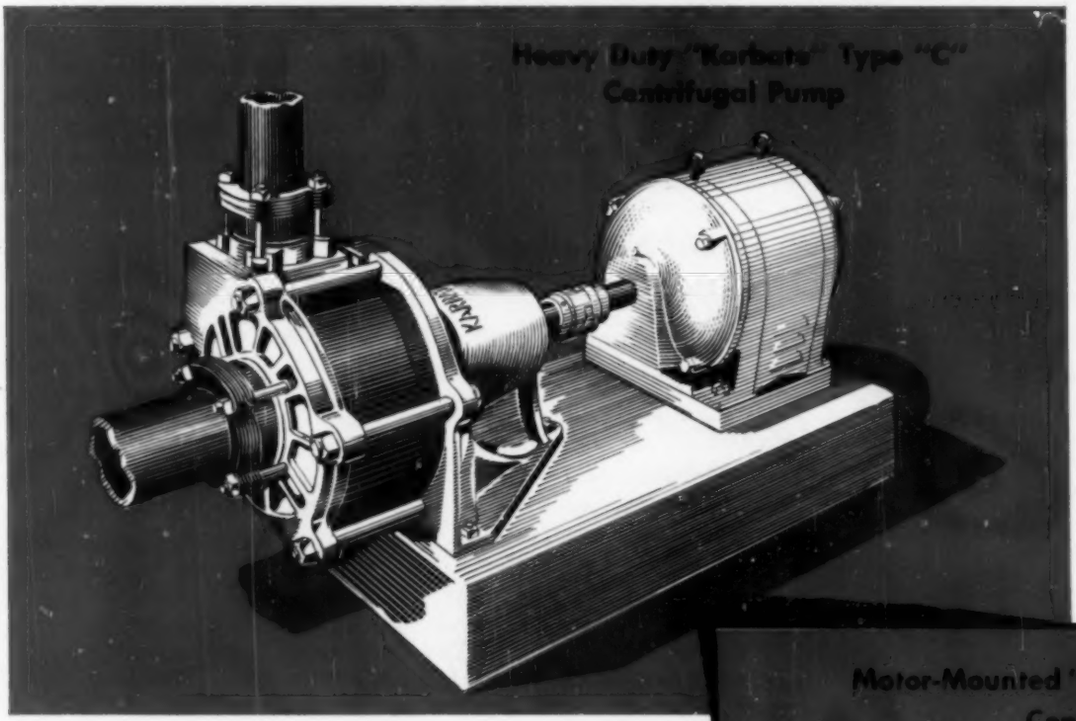

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Editorial

Canada, Country with a Future

THIS issue presents the third article on the electrochemical and electrometallurgical industries of Canada. The fascinating account of the remarkable expansion of these industries and the great hydroelectric developments upon which they depend will be widely appreciated. It is clear that these developments have contributed in great measure to the extraordinary industrial growth of Canada that has taken place in recent years. With less than ten per cent of the population of the United States, Canada has become the sixth ranking industrial power and the third greatest trading nation in the world. The leading exporter of nonferrous metals, Canada supplied nearly 40% of the Allied requirements of aluminum in World War II.

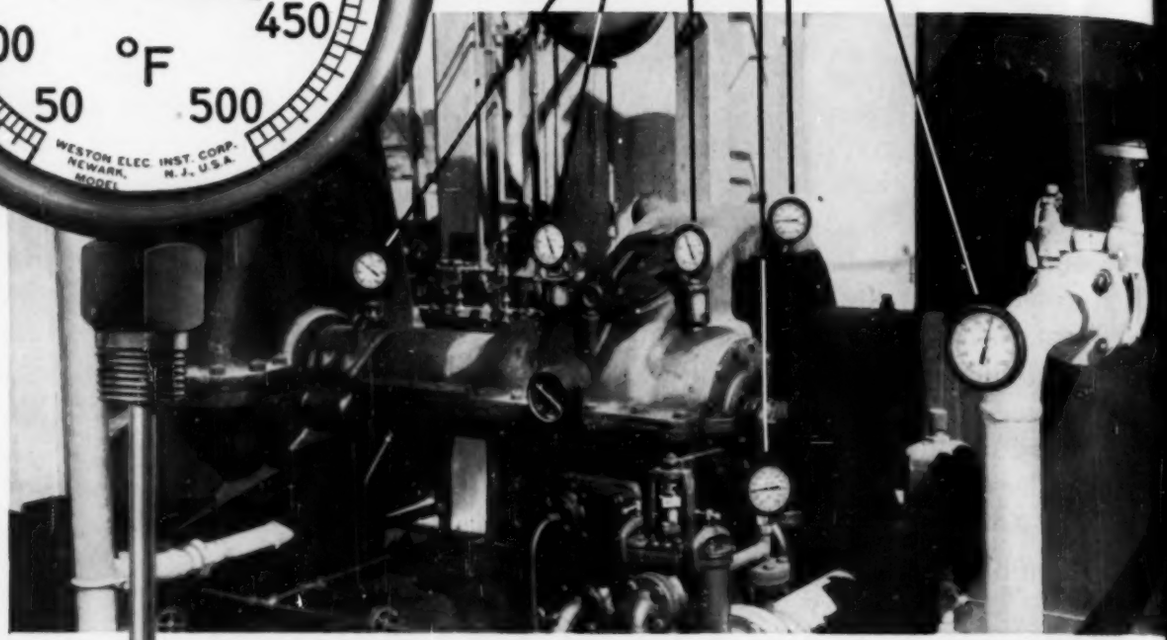
These exciting achievements have grown out of the pioneering electrochemical work of ingenious scientists and engineers on both sides of the border. Among them over the years were such men as E. G. Acheson, Charles M. Hall, F. J. Tone, T. L. Willson, H. Y. Castner, Herbert Dow, L. D. Vorce, Lawrence Addicks, F. M. Beckett, R. A. Witherspoon, F. A. Lidbury, A. F. G. Cadenhead, and R. R. Ridgeway. These and many others deserve acclaim.

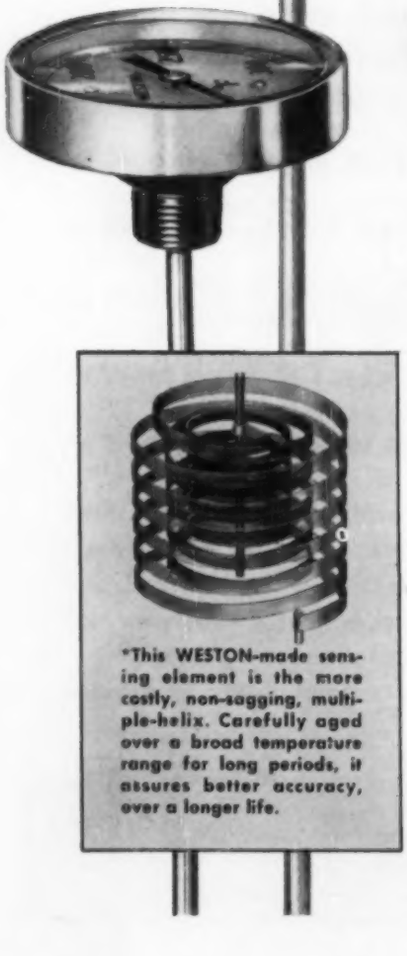
Natural resources of Canada are plentiful, widely distributed, and varied in character. Profiting by the unfortunate experiences of countries like the United States that have wasted a considerable proportion of their natural resources, the Canadian Government has wisely insisted upon conservation and care in the use of these resources. For example, timber lands must be reforested at the same rate that timber is removed. Modern methods of mining and extractive metallurgy are encouraged.

Favored with abundant water power, tremendous natural resources, and a people of great enterprise, it is evident that the present rapidly expanding industrial activity will continue at an accelerated pace. Truly the twentieth century belongs to Canada!

—RMB

AT EVERY CHECKPOINT





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ELECTROCHEMICAL AND ELECTROMETALLURGICAL INDUSTRIES OF CANADA

Part III. Ontario and Manitoba[1]

A. C. Holm[2]

Introduction

In this, the third of a series of four articles describing the electrochemical and electrometallurgical industries of Canada, together with that nation's major power developments, our tour will start in the Province of Ontario and proceed westward through Manitoba; Saskatchewan, Alberta, British Columbia, the Yukon Territory and the Northwest Territories will be discussed in the March issue.

Across the immense part of Canada from the Ottawa River and James Bay to the Pacific, and from the Great Lakes north to the Arctic, there are vast resources not only of raw materials but also of power to process them.

Not the least of the resources, of course, is uranium, and studies are now going forward toward the production of electric power by atomic-driven generators. But there are tremendous stores of natural gas and of coal which have hardly been tapped yet. And there is a wealth of water power still to be harnessed, particularly on the fringes north of the present industrial areas.

Here, estimated at December 31, 1953, for the five westerly provinces and the Territories, are the hydroelectric developments, the water power remaining to be developed, and the year's production of electricity from all sources:

Province	*Water resources (Thousand hp) developed*	*undeveloped*	*Production 1953 (Million kwh)*
Ontario	3981	5458	21,700
Manitoba	717	6513	3008
Saskatchewan	112	1343	1173
Alberta	208	1422	1362
British Columbia	1768	12,532	7650
Yukon & N.W.T.	33	1028	64

The Province of Ontario

Canada's second largest province in physical area (412,582 square miles) and largest in population (4,897,000), Ontario has the distinction of being the most highly industrialized province in the nation, a position it has maintained for over 70 years. Favored in its southern portion by a mild climate (Canada's southernmost projection in Ontario lies farther south than a large sector of the United States) and fertile soil, Ontario early attracted large numbers of settlers. The steadily growing population spurred on local manufacturing, and these two have since advanced vigorously hand in hand so that Ontario now accounts for one-third of Canada's population and about one-half of her manufactured goods.

Important factors in the industrial growth of Ontario have been the development of its great resources of minerals, water powers, and forests, as well as its location on the Great-Lakes—St. Lawrence shipping channels. For half a century Ontario has led all of Canada in mineral production, with some 35% in value of the nation's mineral output originating in this province. Ontario took an early lead in developing hydroelectric power, and while it gradually surrendered first place to Quebec in the nineteen-twenties it still produces some 30% of Canada's total power and more kwh per capita than any whole nation in the world except Norway. Its forests turn out about 27% in value of the nation's pulp and paper and some 16% of its sawmill products. And Ontario's location on the shores of the Great Lakes and the St. Lawrence River (the province has a fresh-water shoreline of 2362 miles) has permitted cheap transportation of raw materials and products. Of special importance has been the relatively easy access to the coal and iron ore of the neighboring states, for Ontario has no coal, and until recent years produced no iron ore in quantity. Not to be overlooked also is the fact that Ontario's varied farm crops can support a large industrial population; the total cash return from farm crops is greater than in any other province.

The varied and numerous manufacturing industries of Ontario are the mainstay of its production, accounting for some two-thirds of the total dollar value of the province's output. These manufacturing industries represent the following percentages of total Canadian manufacture: automotive 96, agricultural implements 96, heavy electrical machinery 95, rubber goods 81, primary iron and steel 74—and many others in this same range; in all, about 50% of total Canadian manufacture. Volume of manufactured products from Ontario has doubled from 1942 to 1952 and is still expanding rapidly.

So vast has become the output of Ontario's factories that its electroproducts industry, large and vigorous though it be, is finding itself gradually receding in relative importance in the province's economy. For a decade or two after the harnessing of Niagara, Ontario led all of Canada in electrometallurgical and electrochemical production. But this supremacy was gradually relinquished to the Province of Quebec as the latter developed its own larger hydroelectric resources and began to outstrip Ontario in the production of low-cost hydro power. The tremendous upsurge of manufacturing in Ontario has actually had the effect of impeding the normal expansion of Ontario's electroproducts industries by avidly outbidding the latter for any new or surplus power and, in fact, at times creating serious power shortages. Ontario is rapidly approaching full development of all its economic hydroelectric power resources and has already been forced to resort to steam power in large quantity, although

[1] This is the third in a series of articles on Canada provided by A. C. Holm, Canadian Regional Editor.

[2] Shawinigan Chemicals Limited, Shawinigan Falls, Quebec, Canada.

it lacks any cheap indigenous fuel for this purpose. The eagerly awaited development of the St. Lawrence Waterway, which now appears imminent, would provide Ontario with an additional 1,100,000 hp. This, together with other hydro developments now under way, would probably take care of the province's growth in power demand for about the next ten years. The probability is, however, that the major share of this additional power will be snapped up by Ontario's new and expanding factories, leaving relatively little for the electroproducts industries. However, despite these difficulties of rising costs and decreasing availability of power, Ontario's electrometallurgical and electrochemical industries are still maintaining a high rate of production and a healthy growth. Of particular importance is the output of calcium cyanamide, ferroalloys, artificial abrasives, graphite, electrolytic nickel and copper, magnesium, and chlorine.

Raw Materials

Of the indigenous minerals, Ontario's electroproducts industries have made use mainly of salt, limestone, sand and quartz, dolomite, shale (for rock wool), and ores of nickel, copper, and cobalt. Imported from other provinces, from the U. S., or abroad are such raw materials as coal, manganese and chrome ore, bauxite, and a certain amount of steel scrap. As by-products of the electrolytic refining of its metal ores, Ontario also recovers gold, silver, platinum and other precious metals, selenium, and tellurium. Other important mineral products of Ontario include iron ore, gold and silver, arsenic, lime and cement, clay products and building stone, nepheline syenite, fluorspar, mica, and asbestos. From its smelting operations Ontario also recovers liquid SO_2 and will soon recover elemental sulfur. Ontario also has Canada's only refinery for uranium and radium, supplied with ore from the Northwest Territories. Promising showings of uranium ore are now being investigated in the Haliburton and Algoma areas of Ontario. Of interest also is a recent find of columbium-tantalum ore under Lake Nipissing near North Bay. The mineral-rich Canadian Shield traverses Northern Ontario, and year after year, as exploration proceeds, new indications of mineral wealth are unearthed.

Electric Power

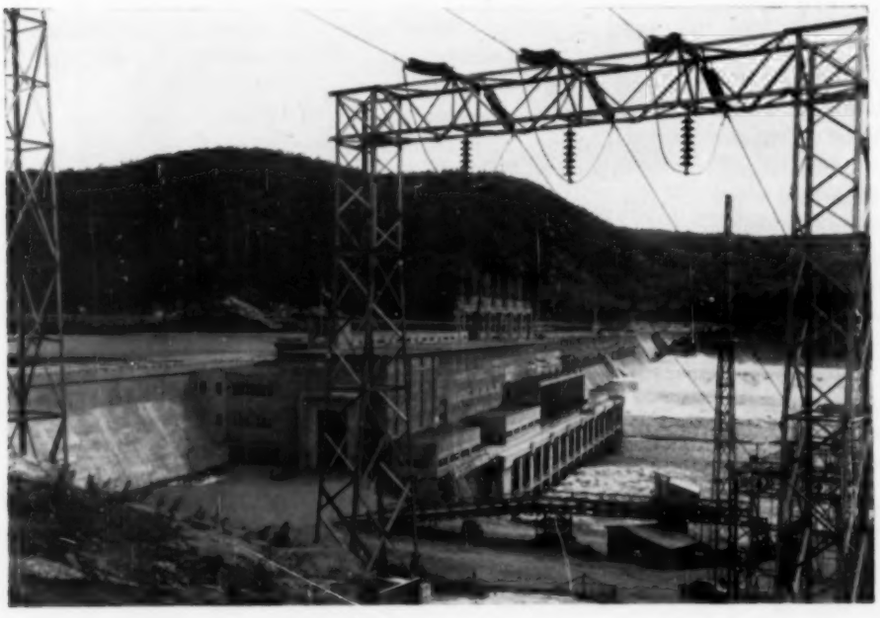
For the further production of electricity to power its rapid industrial and commercial expansion, the Province of Ontario is at the point of proceeding with two developments which have had international attention. First Ontario has laid plans for the harnessing of atomic reactors to drive generators. And second, it is about to start work on the Canadian half of the St. Lawrence Waterway development to produce more than a million horsepower. The Ontario Hydro-Electric Commission, the government-sponsored body which is Canada's largest single public utility, with a present capacity at present of about 4 million hp, is working hand-in-hand with Canada's federal government in both these projects.

In the plan for atomic-generated electricity, the Commission is working jointly with a federally-owned corporation, Atomic Energy of Canada Limited, in a "feasibility study" being carried on at Chalk River, Ontario, where Canada's work in atomic energy has been concentrated since World War II days. No target-date has been set yet for the first production of atomic-generated power, but it's believed that Canada is probably farther ahead than any other country in harnessing the atom for peace-time uses.

In the development of hydroelectric power from the International Rapids section of the St. Lawrence River, Ontario is acting as the agency appointed by the federal government just as New York State has been designated by the United States Government to harness the American share of the riverflow. No schedule has been set for completion of this job, either, but it is expected that, despite delays through actions in American courts, work will start during the coming spring. The seaway, an accompaniment to the power project, is expected to be built by the Canadian government itself.

Since the end of World War II, Ontario Hydro has completed 13 new power developments, all but two of them hydroelectric. Another, the largest of all, is now approaching completion. Named Sir Adam Beck No. 2, it is a 1,260-000-hp development on the Niagara River, adjoining the 560,000-hp plant—Sir Adam Beck No. 1—at Queenston, and like the older one will use water drawn from the river above the cataract and carried, in this case by giant twin tunnels, 5½ miles to the penstocks which drop it about 300 feet to the turbines. The first units are to be in operation this year, and all of them by mid-1956.

With the half-dozen other plants which it operates on the Niagara and Welland Canal by using the Canadian share of Lake Erie's outflow, Ontario Hydro will then be developing



Last of Ontario Hydro's three postwar Ottawa River plaats which harness a total of 942,000 hp on a 174-mile stretch of the river, is the Otto Holden generating station. This giant, named after Hydro's assistant general manager-engineering, Dr. Otto Holden, has a dependable peak capacity of 273,000 hp following completion early in 1953 with eight units in service. The station went into operation initially in June 1952.

more than 2,500,000 hp within that area of a few square miles. And including the nearly 60 plants which it operates in other parts of the province, and the power it buys under long-term contract, principally from Quebec, the capacity of the Commission will exceed 5,800,000 hp. All of its plants, except one at Toronto and another at Windsor, with a combined capacity of about 900,000 hp, are hydroelectric.

Ontario's fully-developed share of the Ottawa River (the rest being under Quebec's control) yields more than 1,100,000 hp. The largest of those Ontario Hydro plants on the Ottawa are Des Joachims, of 496,000 hp, and Otto Holden, of 264,000.

In all, there are 99 hydroelectric plants in the province, with a total generating capacity of about 4,000,000 hp. Most of the plants not owned or operated by the provincial commission are devoted largely to the production of power for individual industries.

By the end of 1953, Ontario Hydro had completed more than one-third of its gigantic project to convert to 60-cycle circuits the frequency in about 12,000 square miles of southwestern Ontario, with nearly one million household, farm, commercial, and industrial customers. In the past, that area has constituted a 25-cycle "island" surrounded by the standard 60-cycle service. Cost of the complete conversion operation, which was started in 1949, is estimated now at about $400,000,000; approximately 5,000,000 pieces of frequency-sensitive electrical equipment are being changed over for 60-cycle operation, or replaced entirely, at the Commission's expense. Newer generating stations have been designed for 60 cycles, and in older ones the frequency is being altered.

Last year saw, too, completion of an agreement for an international exchange of emergency power. Transmission lines crossed the Detroit and St. Clair Rivers to permit Ontario Hydro and the Detroit Edison Company to send one another power, as required, on the two systems—between Windsor, Ontario, and Detroit, and between Sarnia, Ontario, and Marysville, near Port Huron, Mich.

Nickel and Copper

Nickel is one of Ontario's most important products, representing as it does over 85% of the free world's output of this metal. In 1952 this province produced some 140,000 tons of nickel in all forms. In Canada up until now Ontario has been the only producer of nickel; a nickel-copper ore is just coming into production in Manitoba. After gold, nickel has contributed the most to Ontario's total output value of minerals since 1900, and it is followed by copper. Practically all of Ontario's nickel and copper is derived from the immense sulfide ore-bodies of the Sudbury area. These Sudbury mines also produce about 48% of Canada's copper.

There are two large operators in the Sudbury area, the International Nickel Company of Canada Limited and the Falconbridge Nickel Mines Limited. The latter company, holding contracts with the U. S. Government for nickel, copper, and cobalt, has a capacity for some 30 million lb of nickel a year and has embarked on a program designed to double its capacity. Falconbridge operates a smelter in Ontario, but ships all of its nickel and copper as a matte to its Norwegian plant for refining. The International Nickel Company of Canada operates a smelter at Copper Cliff and Coniston and a nickel refinery at Port Colborne, Ontario. Some of its nickel is exported as nickel oxide or as matte, but about 60% is in the form of refined electrolytic nickel. In 1952, about 249,000,000 lb of nickel in all forms, i.e., over 75% of the nickel used by the free world, was produced by "Inco." Inco's copper is refined electrolytically at Copper Cliff; output in 1952 was about 234,000,000 lb. A minor portion of nickel and copper is shipped as a matte to the International Nickel Company's plant at Huntington, West Virginia, for the production of Monel metal.

The earliest corporate unit of what is now the International Nickel Company of Canada Limited was the Canadian Copper Company, formed in 1886, which built a smelter at Copper Cliff in 1887 to roast sulfide ores and later produced a copper-nickel matte. This company also experimented for several years with an electrolytic nickel refining process. At first the matte was shipped directly to the Orford Company at Bayonne, New Jersey, for refining; after 1899 it was given a further smelting treatment at the Ontario Smelting Works of the Orford Company at Copper Cliff, before refining at Bayonne. When the Orford Company adopted the electrolytic refining process of the Canadian Copper Company, the two firms amalgamated as the International Nickel Company in 1902. After the formation of the International Nickel Company of Canada Limited (in 1916) a modern refinery was opened at Port Colborne, Ontario, in 1918 and all the refining operations transferred to it from the Bayonne refinery, which closed down in 1922. In 1929, a merger was effected with the Mond Nickel Company to simplify development of adjoining mining properties, and this amalgamation gave Inco another smelter at Coniston, Ontario, a nickel refinery at Clydach, Wales, and a precious metals refinery at Acton, England.

Up to about 1930 the Port Colborne refinery received a high grade Bessemer matte from Copper Cliff, separated nickel and copper sulfides by the Orford process, produced nickel oxide and electrolytic nickel, and shipped blister copper to U. S. custom electrolytic refineries. With the advent of selective flotation of nickel and copper sulfides at Copper Cliff, it became possible in 1930 to transfer the Orford process to this smelter, carry on only electrolytic refining of nickel at Port Colborne, and to undertake electrolytic refining of blister copper right at Copper Cliff. The latter was first done by the Ontario Refining Company, a partly owned subsidiary. In 1935 this company was also absorbed by the International Nickel Company as the wholly owned "Copper Division" of Inco.

Late in 1948 Inco started to replace the Orford process, which had been used for nearly 60 years, by the matte separation process. In these operations, which have the object of separating copper, nickel, and platinum metals in nickel matte, the matte is subjected to controlled cooling, grinding, and flotation. The entire output of nickel at Copper Cliff is now handled by this new process. The nickel oxide sinter produced contains about 75% nickel, and is shipped to the company's refineries at Port Colborne, Ontario, and Clydach, Wales, as well as to market and to the U. S. subsidiary's plant at Huntington, West Virginia.

As another trail-blazing innovation, Inco has adopted in the past two years the flash smelting with oxygen of its copper sulfide concentrates, replacing costly powdered coal, and permitting greater utilization of sulfur in the smelter gas, e.g., as liquid sulfur dioxide. It has recently also announced a $16 million program to supplement its present 250 million lb a year nickel production by the new treatment of low-grade nickel-bearing pyrrhotite ores previously considered uneconomic. This process will produce as a by-product high-grade iron ore containing some 65% iron, and may permit further recovery of sulfur. And finally, as another part of an expansion and conversion program undertaken

since the war which has already cost over $150 millions, Inco has been revamping underground mining operations to permit it to hoist 13,000,000 tons of ore per year (67% more than in 1951), the largest nonferrous underground operation in the world.

Electrolytic nickel is produced at the Port Colborne refinery of the International Nickel Company of Canada by the electrolysis of a sulfate-chloride electrolyte, with direct current supplied by rotary converters. Raw material is nickel oxide produced at Copper Cliff. Production is in the order of 75,000 tons per year.

Here there are also two small electric furnace operations. In a submerged-arc type of furnace, backed by a 1000-kva transformer, slag recovered from the nickel anode melting furnaces is treated to reclaim metal, which is recycled to the anode furnaces. In a smaller furnace, energized by a 500-kva transformer, electrolytic cell residues are melted and reduced to place the material in a form suitable for subsequent extraction of the precious metals. A large number of valuable metals are recovered in impure form as by-products of the nickel refining operation, e.g., gold, silver, platinum, and cobalt. These crude metal compounds are shipped back to Copper Cliff for further processing; cobalt oxide goes to the refinery at Clydach, Wales.

Power is supplied to the Port Colborne refinery from the Niagara River developments of the Ontario Hydro-Electric Power Commission, as 25 cycle power.

Electrolytic copper is produced at Inco's Copper Cliff refinery, which has a capacity of 168,000 tons of refined copper per year. The plant contains some 1350 deposition tanks, and d-c power is supplied by six motor generator sets of 6000 amp, 80–160 volt rating. The raw material is blister copper produced at the Copper Cliff smelter by oxygen flash smelting of copper sulfide concentrates.

Insoluble portions of the crude copper anodes collect in the bottom of the electrolytic cells as a sludge, which contains gold, silver, and platinum metals, selenium and tellurium, and minor amounts of other metals. Treatment of this sludge, together with the residues from the electrolytic nickel cells at Port Colborne, is carried on at Copper Cliff to produce refined gold, silver, selenium, and tellurium. Preliminary refining of the platinum group metals is done at Copper Cliff, but the concentrates are shipped to the company's precious metal refinery at Acton (near London) England, which produces pure platinum, palladium, rhodium, iridium, and ruthenium from these concentrates.

Certain electrothermic operations are also of interest at Copper Cliff. Copper sulfide concentrates obtained by the matte flotation separation process (from high-nickel matte) are melted in an electric arc furnace. Power is supplied to this furnace by a 6000-kva transformer at 80–100 volts and up to 30,000 amp per phase. In melting down refined copper cathodes, two 3-phase direct-arc type furnaces are used, each 15 ft in diameter with a holding capacity of 30 tons. These furnaces are supplied by a 4000-kva transformer at 46–120 volts, and run at about 21,000 amp per phase. This operation was pioneered by Inco.

Power for Inco's Copper Cliff operations comes from the Ontario Hydro's Abitibi Canyon development and from generating stations of the Huronian Company, a subsidiary, on the Spanish and Vermillion Rivers.

Gold and silver are recovered by electrolytic means from the International Nickel Company's cell residues. At Copper Cliff, gold is electrolyzed in Wohlwill cells and silver in Balbach-Thum cells.

Selenium and tellurium are produced at Copper Cliff from recovered residues of the copper cells. Production of selenium in 1952 was about 88,600 lb, of tellurium about 5,700 lb. Capacity of the plant is believed to be much higher for both metals.

Cobalt

Ontario has for many years been Canada's leading producer of cobalt, formerly from ores worked mainly for their silver content. Since 1950, with demand for the metal pyramiding due to its use in high-temperature alloys, permanent magnets, stellite alloys, etc., ores of lower silver content are being exploited. These come mainly from the Cobalt and Gowganda areas of Northern Ontario, and are being treated at Canada's one operating cobalt smelter, the Deloro Smelting and Refining Company Limited at Deloro, Ontario, near Belleville.

As a sign of the recent activity in cobalt, a second smelter is being erected in Ontario by Cobalt Chemicals Limited, and in Alberta the Sherritt Gordon Mines Limited is completing a refinery at Fort Saskatchewan which will produce cobalt as well as nickel and copper.

The total cobalt produced in Canada (mainly in Ontario) in the form of metal, oxides and other salts, and exported ores, has grown as follows:

1950—	583,806 lb
1951—	951,607 lb
1952—	1,421,923 lb

The Deloro Smelting and Refining Company, Limited at Deloro, Ontario, makes use of electric furnaces in some of its smelting, melting, and refining operations. In a Pittsburgh Lectromelt 150-kva, 3-phase smelting furnace with 4-in. diameter electrodes some 3–5 tons of cobalt-silver ore are smelted per day to yield a bullion containing about 75–87% of the silver, a speiss with about 98–99.5% of the cobalt and 25–13% of the silver, and a slag. The ore, which may run 2000–5000 oz Ag per ton, 5–7% Co, 25–30% As, 5–10% Fe, 25–30% gangue, is fluxed with iron ore, silica, or lime, and coke for reduction. The power consumption averages 80 kwh per ton of charge, and the electrode consumption 3–4 lb per ton.

The melting and refining of cobalt metal or of cobalt-chrome-tungsten alloys is carried out in two Moore Rapid Lectromelt furnaces, single-phase, 100 kva, with 2½ in. diameter graphite electrodes. The rated capacity is 125 lb/hr.

High cobalt-base alloys are melted and deoxidized in three 75-kw Detroit indirect-arc rocking-type furnaces lined with magnesite refractory. The melt, made without slag, comprises prime pig metal, revert and prime metals to balance out the charge.

Magnesium and Calcium

One of Canada's two producers of magnesium, and its only producer of metallic calcium, is located in Ontario. Dominion Magnesium Limited, at Haley (near Renfrew). This plant came into operation in 1942 to produce high-purity magnesium by the Pidgeon process. Named after its Canadian inventor, this process involves the reduction of calcined magnesite or dolomite by the use of ferrosilicon. At Haley, a briquetted charge of calcined dolomite and finely ground ferrosilicon is heated in highly evacuated, cylindrical retorts of heat-resisting steel to about 1150°C in electrically heated furnaces. The reduced volatilized magnesium con-

lenses in the cool head of the retort as large crystals. The metal is of exceptionally high purity, particularly as regards iron. Rated capacity when operated entirely on magnesium is about 12,000,000 lb per year.

Since 1947 this plant also produces high purity calcium metal by a similar process in the same equipment. It is reported that aluminum is used to reduce calcium oxide in this case. Currently, part of the retorts are operating on calcium production, part on magnesium.

This plant is also equipped to produce extrusions in magnesium or aluminum metals, using for this purpose a 2400 ton Loewry press, which has a yearly capacity of 1800 tons of magnesium extrusions.

Dominion Magnesium Limited has also experimented with production of titanium metal on a pilot-plant scale.

Caustic Soda and Chlorine

Ontario produces the major share of Canada's chlorine and caustic soda, seven of the ten present producers being located in this province. The earliest commercial production of chlorine in Canada took place at Kincardine, Ontario, where the Ontario Peoples' Salt & Soda Company operated a diaphragm cell in the 1890's and at Sault-Ste-Marie, Ontario, where some 120 Rhodin mercury cells were operated in 1901 by the Canadian Electro-Chemical Company Ltd. These enterprises did not continue long in operation, however, and the oldest existing chlorine plant in Canada is the one now operated at Windsor by Canadian Industries Limited.

Canadian Industries Limited plant at Windsor, Ontario, (at that time the Canadian Salt Company), installed the vertical diaphragm type of cell known as the Gibbs cell in 1910, and this type of cell is still used at Windsor. The plant has been expanded over tenfold since then and today covers a site of some 50 acres on top of the salt beds some 1600 ft below, from which the salt is pumped as a brine. The Windsor Works employs 314, and its chief products are liquid chlorine, caustic soda, ammonia, and ferric chloride. The chlorine is sold chiefly to pulp and paper companies; half of the caustic is sold as a liquid to soap companies, etc., while the remainder is sold as solid or flake caustic. Ammonia made from cell hydrogen goes to C.I.L.'s fertilizer plants, chiefly, while residual chlorine is used to produce ferric chloride, sold for water and sewage treatment. Power for this plant comes from the Ontario Hydro. Cell current is 1000 amp, and a cell line is operated at 250 volts.

A second C.I.L. plant at Cornwall, Ontario, was started in 1935. This plant employs the mercury cell, and has about 135 employees. Chlorine and caustic are sold mainly to pulp and paper mills, and hydrogen to a neighboring chemical plant.

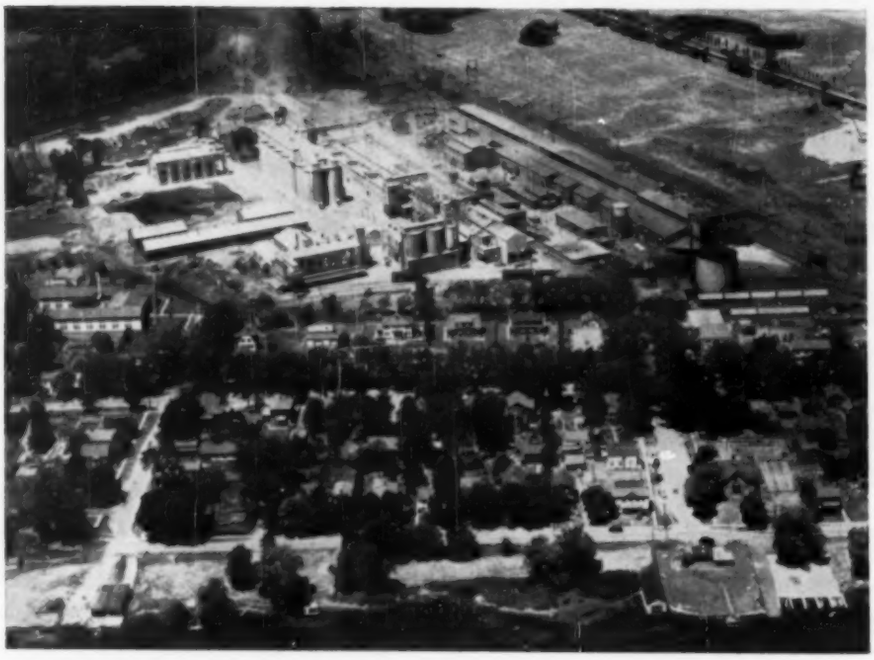
Chlorine plants are operated also by the following pulp and paper mills in Ontario, for their own use: Howard Smith Paper Mills Limited, Cornwall; The K V P Company Limited, Espanola; Canadian International Paper Company, Temiskaming; and Marathon Paper Mills of Canada Ltd., Marathon. These plants are of a conventional design, except for the one at Marathon. The Marathon unit, brought into operation in 1952, employs De Nora mercury cells with the Achille modification for the simultaneous production of sodium sulfide. The sodium amalgam in this operation is in part decomposed to caustic, and partly reacted with a polysulfide solution to form sodium sulfide, the latter being used for pulp cooking. Chlorine and caustic soda are used for bleach purposes, while part of the hydrogen is combined with a little chlorine to make hydrochloric acid, used for *p*H adjustments of the brine. The installation consists of 30 De Nora mercury cells, fed by 3 mechanical rectifiers of 10,000 amp each. A.C. power is supplied to the rectifiers from the mill's turbogenerators through step-down transformers.

Dow Chemical of Canada Limited, at Sarnia, Ontario, also operates a mercury cell chlorine plant. Most of the output is used in the company's other operations, viz., production of ethylene glycol, hydrochloric acid, chlorinated solvents, ammonia, styrene, etc. This company came into being in 1942 as part of a team organized to produce synthetic rubber at Sarnia during World War II; the chlorine plant is a postwar addition, enlarged in 1952.

Calcium Cyanamide, Cyanide, and Related Products

The plant of North American Cyanamid Limited at Niagara Falls, Ontario, is the only cyanamid plant in the western hemisphere and the largest of its kind in the world. A wholly owned subsidiary of the American Cyanamid Company, it started producing calcium cyanamide in 1909 at a rate of about 5000 tons a year. Today it has a capacity of about 270,000 tons of cyanamid per year, and produces

Ferroalloys plant of the Electro Metallurgical Company of Canada, Limited, located on Welland Canal at Welland, Ontario.



Norton Company's artificial abrasives plant at Chippawa, Ontario

many other products as well. These include dicyandiamide, melamine and melamine resins, urea and urea resins, and calcium cyanide. During the war, nitroguanidine was also made from dicyandiamide. Much of the cyanamide and cyanide is exported to the United States.

The intermediate in the manufacture of cyanamid is calcium carbide, and NACL operates five carbide furnaces to produce it, three of 20,000 kw or better and two of 10,000 kw. They are charged with lime (burned in rotary kilns) and coke, and are tapped continuously onto a special cooling conveyor. Cooled carbide is crushed and milled and charged to one of a multitude of batch ovens where it is reacted with nitrogen under controlled conditions to form crude cyanamid. To start the furnace a zone of local high temperature is created within the charge by means of a carbon electrode; about three hours is sufficient heating to start the reaction. Since this is an exothermic reaction, no additional heat is required for its completion. The whole nitrification cycle, including cooling, requires about seven days for a four-ton charge of carbide.

Crude calcium cyanide (Black cyanide) is made from cyanamid and salt by fusion in a three-phase electric furnace. The product has a sodium cyanide equivalent of 48–50%, and has found its greatest use in cyanidation of gold and silver ores.

Sodium silicate production was started in 1933, using an electric resistor furnace to fuse soda ash and sand together in a continuously operated unit.

A $4 million expansion program was completed at the Niagara Falls plant in 1952, involving an additional carbide furnace (the fifth) and other new production facilities. This latest furnace is equipped with hydraulically controlled Soederberg electrodes of a rectangular shape and has one three-phase transformer.

Power is supplied to North American Cyanamid Limited from the Niagara River developments of the Ontario Hydro.

Ferroalloys

There are two producers of ferroalloys in Ontario, both operating to a large extent on imported ores. Four producers of artificial abrasives (listed later) recover a small quantity of ferrosilicon as a by-product of their operations.

The Electro Metallurgical Company of Canada, Limited, plant at Welland, Ontario, was established in 1907, the firs ferroalloys plant in Canada. Production facilities are availabl for ferromanganese, ferrosilicon, silico manganese, ferro chrome—both high and low carbon grades, and speci briquetted ferroalloys for the iron foundry industry. Capacit is well in excess of domestic requirements and an extensi export business is enjoyed.

Located in close proximity to Niagara Falls, and possessin dock facilities on the Welland Ship Canal, this plant is we situated to receive large blocks of power (from the Ontari Hydro) and to move large tonnages of raw materials an products.

The Chromium Mining and Smelting Corporation a Sault-Ste-Marie, Ontario, began operations in 1935, having taken over the idle plant of Superior Alloys Limited which started up in 1929 to make ferroalloys. Products are ferro silicon and ferrochrome and the exothermic alloys Chrom-X Sil-X, and Chrom-Sil-X. This company has done considerabl development work on the use of domestic low-grade chrom ores and on the production of exothermic ferroalloys.

Artificial Abrasives and Refractories

Ontario has long had a very large output of artificial abrasives from plants in the Niagara Falls area, where the great quantities of low-cost electric power required have been available. These plants supply a major share of U. S. require ments for crude abrasives, and export to other countries as well.

The Canadian Carborundum Company Limited ha produced fused alumina (Aloxite) at Niagara Falls, Ontario since 1916.

Norton Company, at Chippawa, Ontario, has operated since 1910 and now produces such materials as fused alumina (Alundum), silicon carbide (Crystolon), fused magnesi (Magnorite), and boron carbide (Norbide) as well as zirconi The Chippawa plant has nearly 800 employees.

Exolon Company established its plant at Thorold, Ontario in 1914 to produce silicon carbide and fused alumina.

Lionite Abrasives Limited, at Stamford, Ontario, started in 1950 to produce silicon carbide and fused alumina.

[A more detailed discussion of these operations may be

found in the JOURNAL Vol. 100, No. 3 (March 1953) pp. 61C-64C, in an article by G. R. Finlay and J. A. Upper entitled "Developments in the Abrasives Industry in the Niagara Area, 1945–1953."]

Artificial graphite products.—National Carbon Limited, at Welland, Ontario, manufactures carbon and graphite refractories, electrodes, and electrolytic anodes. A recently completed expansion was purposely designed to afford production capacity considerably in excess of the domestic and export demands experienced to date, in that a major future growth is anticipated in the use of these products, with Canada's vast potential in hydroelectric power. National Carbon Limited is the only producer of artificial graphite in Canada at the present time.

Mineral Wool

An electric furnace process for producing mineral wool has been operated by Spun Rock Wools Limited, at Thorold, Ontario, since 1934, the only operation of its kind in Canada. The raw material, quarried locally, is Rochester dolomitic shale; this is melted in electric furnaces at about 2800°F and poured onto a rotating disk in a thin stream. The centrifugal action of the disk revolving at high speed, combined with the special characteristics of the melt, produces a very long-fibered wool (Spun Rock Wool). By blowing the molten stream with an air-jet a short-fibered material can also be produced. This rock wool is used in thermal insulation applications.

For the melting operation, three 200-kw, 3-phase electric furnaces are used, operated at about 130 volts and 1000 amp per phase. These furnaces are about 5½ ft in diameter and are quite similar in design to the conventional 1-ton steel furnace, except that the furnace pivots on the pouring spout. The furnaces were built by the Volta Manufacturing Company of Welland, Ontario. Operation is more or less continuous and each furnace can produce about 2 tons of rock wool in 24 hours.

Electric Furnace Steel

In keeping with Ontario's leading position in the primary iron and steel and heavy manufacturing industries of Canada, the province has the largest number of electric steel melting furnaces in the country. The total, believed to number 44, is about one-half of the total for all Canada, and the aggregate rated capacity is nearly 650,000 net tons annually, or about 65% of the Canadian total. Some 11 firms operate electric steel furnaces in Ontario.

Atlas Steels Limited, at Welland, Ontario, produces all its steel in six Heroult-type furnaces ranging in size from 5–50 tons capacity. Peak power demand for these furnaces is 35,000 kw, and annual melting capacity is rated at about 200,000 ingot tons per year. Production includes carbon, tool and alloy steels, and a full line of stainless steel sheet, strip, bar, wire, and special forged sections. In recent years, Atlas has installed hot and cold mills for stainless strip, equipment for welded stainless tubing, an automatic powder scarfing machine, and Canada's first continuous commercial casting machine for steel. Power is supplied by Ontario Hydro.

Dominion Foundries and Steel Limited, Hamilton, Ontario, operates five steel-making furnaces, in addition to four open hearths. Two are of 50–60 ton capacity, two about 10 ton, and one about 2½ ton size. Peak power load is about 43,000 kw; annual capacity is reported to be 175,000 tons in the electric furnaces. Equipment for continuous strip annealing has a peak load of 1400 kw and for electrolytic tinning about 2000 kw. The plant has a turbo generator of 1500 kva rating, and Ontario Hydro supplies the balance of power needs.

The Steel Company of Canada, Limited, at Hamilton, Ontario, operates one Heroult-type electric steel furnace with a 20,000 kva transformer, and an average capacity per heat of about 92 tons. This furnace produced about 110,000 net tons in 1952, with an average energy consumption of about 475 kwh per ton. This production is only a small fraction of Stelco's open-hearth steel output.

Ford Motor Company of Canada Limited, at Windsor, Ontario, has 18 electric steel furnaces ranging in size from ¼ to 5 tons, with an annual capacity of about 100,000 net tons.

Of the smaller producers of electric steel in Ontario, Burlington Steel Co. Limited, Hamilton, has one 7 ton furnace; Canada Electric Castings Limited, Orillia, has two 2 ton furnaces; Fahralloy Canada Limited, Orillia, has 3 furnaces ranging from ½ to 2 tons; William Kennedy And Sons Limited, Owen Sound, have 2 electric furnaces, 4 ton and 1-¼ ton; Welland Electric Steel Foundry, Limited, Welland, has 3 furnaces, ranging from ¼ to 1-½ ton size.

Data on the last six firms above were taken from the Dominion Bureau of Statistics publication, "The Primary Iron and Steel Industry 1951," which was issued in June 1953. Some changes may have occurred since then, e.g., two additions may be noted: Sheepbridge Engineering (Canada) Limited has set up an alloy steel plant at Guelph, Ontario, and employs high-frequency induction melting furnaces, with a labor force of 40. Hayward-Tyler of Canada, Limited (formerly of Luton, England) has opened a new stainless steel foundry at Kitchener, Ontario, employing 25.

The above list of direct electroproducts manufactured in the Province of Ontario is believed to be reasonably complete. No attempt has been made to include derivatives of these electroproducts, which are quite numerous, nor to cover applications of electrical energy for straight heating purposes, as in electric steam boilers, or for mechanical operations such as crushing and grinding. Ontario's many mines and paper mills consume a very large amount of power for these purposes.

The Prairie Provinces

Moving westward from Ontario, we cross in succession the three "Prairie Provinces" of Manitoba, Saskatchewan, and Alberta. Together their great plains account for some 95% of the total acreage in wheat, barley, and flax, and about 71% of the occupied farm land of all Canada. These statistics, indicating an essentially agricultural economy, might appear to proffer little of interest in this region for the electrochemist; such is not the case, however. One of Canada's two electrolytic zinc refineries is located here, five electric steel furnaces are in operation, and a chlorine-caustic soda plant is now being built. Hydroelectric resources are ample, and exploitation of tremendous reserves of petroleum, natural gas, lignite, and coal has barely begun. Manufacturing production has increased fourfold in value over the past ten years. It may be surprising to learn that from one-third to one-half of the area of these provinces is covered by forest, and that the often mineral-rich rocks of the Precambrian Canadian Shield, which are so prominent a feature in Northern Ontario and Quebec, also carry through into the northern parts of the Prairie Provinces, underlying almost 60% of the area of Manitoba, 45% of Saskatchewan, and about 5% of Alberta. Mineral exploration is proceeding at a brisk pace and there seems to be a good chance that mineral

exploitation and power production will create further electrochemical and electrometallurgical enterprises in these provinces in the future.

Province of Manitoba

Manitoba has an area of 246,512 square miles and a population of 809,000. Over 95% of its people inhabit the southern, prairie-land half of the province, with Winnipeg, Canada's fourth-largest city, accounting for some 354,000 alone. Manitoba is Canada's fourth-largest manufacturing province and accounts for some 50% of the manufactures of the Prairie Provinces. In 1952, manufacturing output at $630 millions was about double that of primary agriculture; far behind was mineral production at $25 millions, forest products (lumber, pulp, and paper) at $19 millions, and fresh-water fisheries at $7.5 millions.

Minerals

In the way of minerals (2.4% of the Canadian total output), copper and zinc predominate, with gold next and silver, cadmium, selenium, and tellurium, as by-products of copper and zinc smelting, ranking among the metals. This output is largely due to the operation, by the Hudson Bay Mining and Smelting Company Ltd., of the Flin Flon mine, which straddles the Saskatchewan-Manitoba border. Sherritt Gordon Mines Ltd., until September 1951 a large base-metals ore producer at Sherridon, Manitoba, is just now resuming operation at a newly-developed 14 million ton copper-nickel-cobalt ore body some 145 miles to the north at Lynn Lake, Manitoba. The Lynn Lake ore will be shipped to Alberta for treatment, while the Flin Flon ore is smelted in Manitoba. There is also active gold mining carried on, while indications have been found of ores of chromium, lithium, beryllium, and molybdenum, without, however, any exploitation of these taking place as yet. Of interest also is the output of salt, gypsum, lime, cement, clay products, and a little petroleum.

Electric Power

Of Manitoba's power supply of about 870,000 hp, all but 56,000 hp is hydroelectric. That hydro total includes the 108,500-hp capacity of a site which lies just over the provincial border in Saskatchewan and which, owned by a subsidiary of Hudson Bay Mining and Smelting Company, supplies the Flin Flon mining and metallurgical area. About 9000 hp of the capacity within Manitoba itself is owned by mining companies; all the rest is owned by the provincial & municipal governments. Public ownership o the pub supply of power became complete last year w en the pr vincial government bought out the plants of the Winnip Electric Company, which previously divided with the Ci of Winnipeg the generation and distribution of power that metropolis.

The Hudson Bay Mining and Smelting Company Limited plant at Flin Flon, Manitoba, Canada's northernmost electroproducts plant, comprising a copper smelter and electrolytic zinc refinery.

Thus the provincial government, through its power com mission, now owns and operates the three largest plants o the Winnipeg River: Seven Sisters, of 225,500 hp; Gre Falls, of 168,000; and Pine Falls, of 114,000. In addition, is now building, for operation in 1955, the 80,000-hp M Arthur Falls plant at the last undeveloped site on that riv Also on the same river are the two plants owned by th City of Winnipeg: Pointe du Bois, of 105,000 hp, and Sla Falls, of 96,000. Because remaining water power lies almo entirely in the northern part of the province, authorities a now studying the cost of its development and transmissio compared to the thermal production of power in the popu lated southern sections.

The abundant, although undeveloped, hydroelectric re sources of Manitoba's northland, particularly along th Nelson and Churchill Rivers, and the probability of im portant ore deposits being located in the Precambrian rocks of this northern area, offer the possibility that in futur years a large electrometallurgical enterprise might spring up here. Added to this are the existing facilities for deep-wate shipping from the Hudson Bay port of Churchill, Manitob The sea route through Hudson Strait to Liverpool, England from Churchill is only 175 miles longer than the shortes route from Montreal to Liverpool; it is navigable for 98 day of the year. From Churchill also a 510-mile railway lin leads to the south and west to The Pas, Manitoba, whence good transportation facilities exist tying in with transcon tinental rail lines.

The following electrometallurgical establishments are now to be found in Manitoba.

Electrolytic Zinc

The Hudson Bay Mining and Smelting Company Ltd. operates a mine, smelter, and zinc refinery at Flin Flon, Manitoba. This is located on the Manitoba-Saskatchewan border just south of the 55th parallel, and is Canada's most northerly electroproducts industry. The plant went into operation in 1930. Ore is treated by differential flotation to produce a zinc concentrate and a copper concentrate; the flotation tailings contain some gold and silver which are re covered by cyanidation. The copper concentrates are roasted, smelted to a matte, and blown to blister copper in a con verter; this copper is shipped to the electrolytic refinery at Montreal East, Quebec (Canadian Copper Refiners Ltd.), where pure copper is produced and the selenium, tellurium, and gold and silver content is recovered.

The zinc concentrates are roasted and leached, and pure zinc is recovered from the purified leach solution at Flin Flon by electrolysis. Cadmium is a by-product. The zinc cell room has 1180 cells arranged in seven series circuits comprising 160 operating cells each, with 60 standby cells. Each circuit has a nominal rating of 6,000 d-c amp at 600 volts. Each cell has 17 aluminum sheet cathodes and 18 lead-silver anodes. Direct current is supplied by seven motor-generator sets and two mercury-arc rectifiers. Each M.G. set has one 5,000-hp motor driving two motor generators, each rated at 3,000 amp at 575 volts. The rectifiers are rated at 8,000 amp d-c at 600 volts.

Output from Flin Flon is about 40,000 tons per year of blister copper and 65,000 tons of electrolytic zinc, as well as 30 tons annually of high-purity cadmium, 50–60 tons selenium, and over a ton of tellurium as by-products. In 1952 a slag fuming plant was installed to permit recovery of zinc from residues.

Electric power for the plant is obtained from the Island Falls hydroelectric plant in Saskatchewan. This development, located on the Churchill River about 60 miles northwest of Flin Flon, is operated by the Churchill River Power Company, a wholly owned subsidiary of the H.B.M. & S. Co. Ltd., and has an installed capacity of nearly 110,000 hp. It was this power that made possible the economic exploitation of the Flin Flon ore body and the production of electrolytic zinc at this site.

Electric Furnace Steel

Steel for ingots or castings is melted in electric furnaces by the following firms in Manitoba: Manitoba Rolling Mill Co. Ltd., at Selkirk, operates a 6-ton electric furnace as well as open hearths; Manitoba Steel Foundries, Ltd., at Selkirk, operates one 5-ton electric furnace; Vulcan Iron Works Ltd., at Winnipeg, has a 3-ton electric furnace in service.

Note: The final part of this series will appear in the March issue of the JOURNAL.

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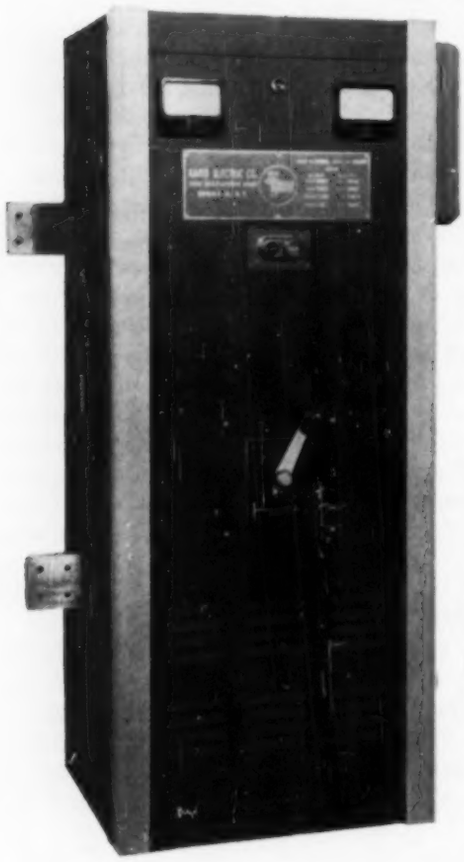

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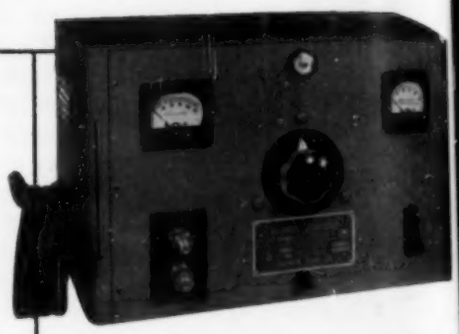

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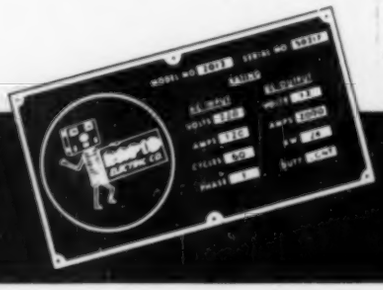

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reduction gave cyclohexyl cyclohexylpropionate, bp 72°–75°/6 mm Hg, $D_4^{25} = 0.9741$, $n_D^{25} = 1.4700$. Saponification with 20% alcoholic potassium hydroxide solution gave cyclohexylpropionic acid, mp 16° C, and cyclohexanol.

Results and Discussion

Effect of current density.—It was found that better yields could be obtained at lower current densities. This is shown in Tables III, IV, and V.

Effect of acid concentration.—It may be seen from the data in Tables VI and VII that stronger acid solution caused the formation of esters; otherwise acid concentration had no noticeable influence on the reduction.

Effect of temperature.—It is seen in Tables VIII and IX that the reduction was favored by high temperatures.

Effect of duration.—Table X shows that yield of product was almost independent of duration of the run. Current efficiency fell, of course, as the run was prolonged beyond the theoretical time.

Effect of pressure.—A special study was undertaken of the effect of high pressure in the course of the reduction. It is seen in Tables XI to XIII that the reduction was favored at high hydrogen pressure, although the effect was not great. Assuming that the reduction at a Pt-pt cathode proceeds by a catalytic mechanism, it would be expected that pressure would increase the rate of reduction of organic compounds. The results obtained, however, are irregular. More detailed conclusion must await further results.

Acknowledgment

It is with great pleasure that the authors responded to the invitation of Professor C. L. Wilson to submit a paper for the Symposium on Electro-Organic Chemistry. The authors express their sincere thanks to him for his kind advice and encouragement.

Any discussion of this paper will appear in a Discussion Section, to be published in the December 1954 issue of the Journal.

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Flexible Leads for Low-Frequency Electric Furnaces

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ABSTRACT

Special problems are encountered in designing cables to transfer power from the bus system to the electrodes of arc furnaces. The requirements for cable are outlined and a brief study made of the various types used. The development of water-cooled cables is traced, and data are given on construction, current ratings, life expectancy, and other characteristics. The conclusion is that this type of cable is a practical solution of the problems encountered.

Introduction

Water-cooled flexible leads, consisting essentially of a flexible conductor inside a flexible metal tube with suitable terminals and water passage, have been in use for many years. One of their most important applications pertains to calcium carbide furnaces.

The electrical resistance of a calcium carbide furnace is low (usually between 1200 and 2500 microhms, depending on the power taken and the nature of the charge). In order to obtain a satisfactory power factor, it is therefore necessary to limit the reactance to a corresponding value. Since reactance is directly proportional to frequency, it presents a greater problem in the design of 60-cycle furnaces than it does for furnaces with power supplied at lower frequencies. The reactance, X, equals $2 \pi fL$ ohms. The inductance, L, depends mainly on the size, shape, length, and arrangement of current-carrying parts.

Fig. 1 and 2, showing schematically the arrangement of low-voltage connections to the electrodes of a carbide furnace designed for low reactance, serve to show the advantage gained by the use of water-cooled flexible leads. Current supplied by transformer [2] is carried to the contact shoes, [10], on the electrodes, [11], [12], and [13], by interlaced bus bars, [3], and uninterlaced connections, [7], [8], and [9], including water-cooled flexible leads, [16]. Single circuits are indicated, whereas in practice multiple circuits, with a corresponding number of electrode contact shoes, are used. Minimum reactance is obtained mainly by (*a*) making all parts of the circuit as short as practicable, (*b*) the use of multiple circuits, (*c*) carrying the interlaced (alternatively plus-minus) bus bars from the transformer to points as near the electrodes as practicable, and (*d*) by completing the delta connections at the electrodes. In this arrangement of current-carrying parts, the flexible leads are exposed to the radiant heat of the furnace and, therefore, they must be water-cooled. If, alternatively, flexible leads made with multiple thin copper strips or bare stranded conductors are located outside the furnace, the length of the uninterlaced connections is increased with a corresponding increase in reactance.

Further advantages are gained in the use of water-cooled flexible leads if they can be mounted in the form of an upright arch, as indicated in Fig. 2. The height of the horizontal connections between the interlaced bus bars, [3], and the electrode, [13], is determined by the amount of clearance under them that is required for furnace operation. Since flexible lead [16] is self-supported, when its terminal connections are arranged to hold it in an arched position it may be installed as indicated. In order to obtain the same clearance with a suspended flexible lead, it would be necessary to raise the interlaced bus bars, [3], together with the horizontal tube, [9], and to increase the length of tube [19]. The self-supported flexible lead of this design therefore provides means for reducing the length and, consequently, the reactance of the electric circuit. Another advantage of the arched position is that the flexible lead has a minimum exposure to the radiant heat of the furnace and to damage by tools used in the operation of the furnace.

The development of a self-supported water-cooled flexible lead suitable for low-frequency electric furnaces is the main subject of this discussion.

Consideration of means for making the flexible leads self-supported when mounted in an arched

[1] Manuscript received April 16, 1953. This paper was prepared for delivery before the New York Meeting, April 12 to 16, 1953.

position led to the choice of a design in which this characteristic is obtained by the use of one or more flat strips of resilient metal which make the leads flexible in a longitudinal plane at right angles to the flat surfaces of the spring strips and comparatively rigid in a transverse direction.

Four arrangements of the spring strips, comprising successive steps in the development, are illustrated by Fig. 3 to 6. The results of accelerated aging tests are tabulated in Table I.

Fig. 3 and 4 serve to illustrate the arrangement of the component parts of both flexible leads I and II, Table I. As indicated in Fig. 3, a conventional water-cooled flexible lead, consisting of flexible conductor [10] soldered in receptacle [9] of terminal [5], having water passages [6]-[7]-[8]-[15] and outer flexible metal tube [30], is provided with spring strips (phosphor-bronze), [20] and [25], firmly fixed to the terminals, [5], by means of silver solder. Fig. 4 is a sectional view of this arrangement. The spring strips make the flexible lead self-supported when its terminal connections are made to hold one end in the position indicated by Fig. 3, and the cable is looped around laterally to a similar parallel terminal in suitable spaced relation. Since in a bend of this shape one spring strip is longer than the other, a flexible lead of this design must be fabricated and maintained with a predetermined shape of bend, i.e., with suitably spaced terminals either parallel or inclined toward one another at a predetermined angle.

Flexible Lead I

The first flexible lead of this design was made with only one spring strip located on the under side of the flexible conductor and having its ends brazed to the conductor strands at the terminals. An accelerated aging test was made on a test lead of this design with results as shown in Table I. The testing apparatus was made to hold the terminals vertical and parallel and with a suitable bending diameter. With one terminal fixed, the other terminal was moved up and down a distance of 3 ft until failure occurred, water pressure being maintained throughout the test. The tabulated results show the number of cycles and the distance traveled by the moving terminal before leakage of the cooling water occurred.

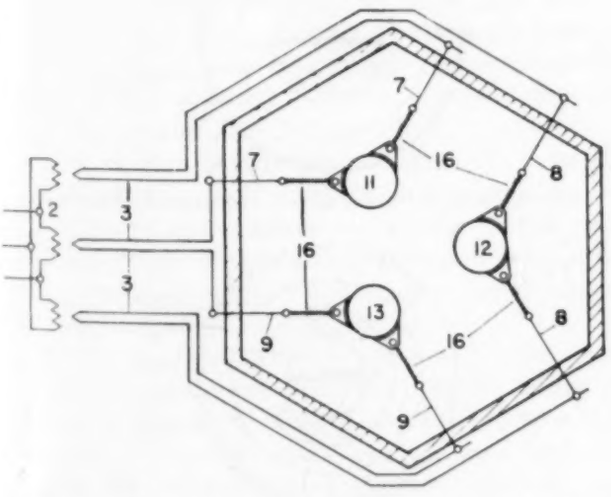

Fig. 1. Low voltage connections for a calcium carbide furnace.

Although measurement of the movement of carbide furnace electrodes indicated that flexible leads with a test performance equal to that of flexible lead I might remain in service two or three years without trouble, in practice it was found that leakage occurred after only about six months of operation. Through breakage of the conductor strands to which the spring strips were brazed and by other causes the spring strips became displaced, thus failing to support the flexible leads in a uniform arch and causing wear on the outer flexible tubes with final leakage.

The discrepancy between the actual life and the life expectancy based on test results is accounted for by the difference between furnace operating conditions and test conditions. The flexible lead on test

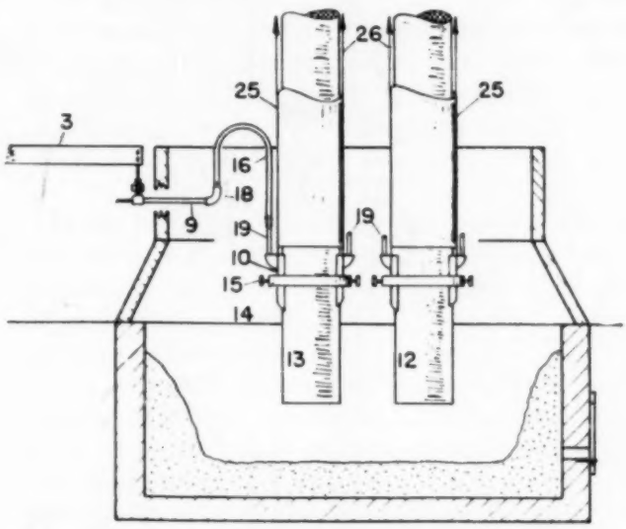

Fig. 2. Low voltage connections for a calcium carbide furnace.

TABLE I. *Results of accelerated aging tests on self-supported flexible leads*

Ref. No.	Description	Cycles traveled free end	Traveled distance ft
I	1 spring strip in water passage	3,770	22,620
II	2 spring strips in water passage	12,616	75,696
III	Spring at center of 4-segment conductor	11,120	66,720
IV	Spring at center concentric design	31,594	189,564

was constantly held at the bending diameter for which it was made and with the spring strip flexing only in a vertical plane passing longitudinally through its center, whereas, because of limited horizontal movement of the electrodes at the elevation of the contact shoes, flexible leads in service were subjected to stresses resulting from changes in bending diameter and alignment.

Flexible Lead II

The design of the flexible leads was then changed to that shown in Fig. 3 and 4. The use of two spring strips, firmly fixed to the terminals, served to give the flexible leads more adequate support and, at the same time, the additional spring strip reduced wear on the outer flexible tube caused by relative motion between the flexible conductor and the flexible tube.

The accelerated aging test indicated considerable improvement as compared with flexible lead I. It has been found that the life of the lead in service was approximately doubled by the changes in its construction. However, the spring strips still tended to become displaced with results as described above. Improvement was only in the length of service obtained before leakage occurred.

Flexible Lead III

A further development of the flexible lead was made by securing a single spring strip, [20], at the center of a flexible conductor, [10], made in four segments as shown in Fig. 5. The assembly was held together with a neoprene-insulated binding wire, [35], which was also designed to prevent frictional wear on the inner surfaces of the flexible tubing.

The accelerated aging test (see Table I) indicated that a flexible lead of this construction was not improved with respect to life expectancy. The test life was limited because of irregular bending of the outer flexible tube. The flexible tubing tended to bend sharply at two or three points, with final failure caused by leakage at one of them. It was later found that the irregularity of the flexing was caused by displacement of the binding wire, [35], Fig. 5. A wire braid is now used to hold the segments in place.

Flexible Lead IV

Flexible lead IV (Fig. 6) includes a flexible conductor with a core of unusual construction. A strip of resilient metal, [20], is embedded at the center of

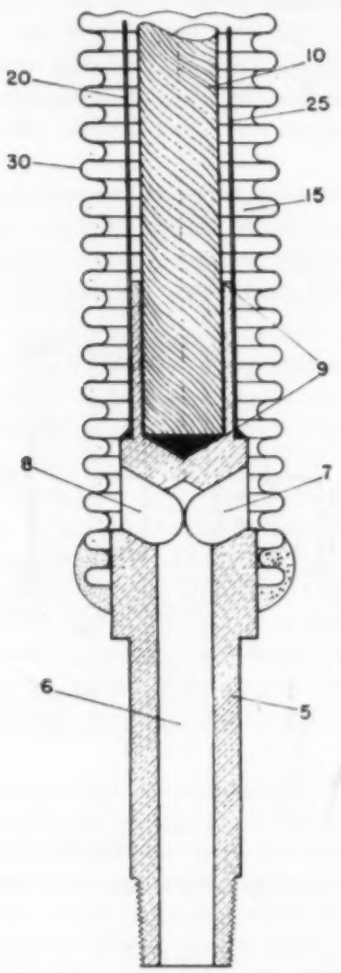

Fig. 3. Sectional views of self-supported flexible leads

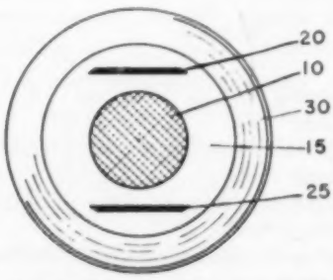

Fig. 4. Sectional views of self-supported flexible leads

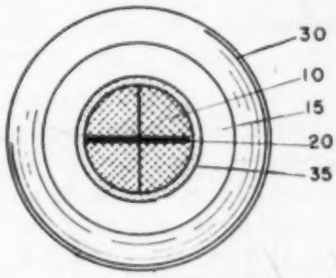

Fig. 5. Sectional views of self-supported flexible leads

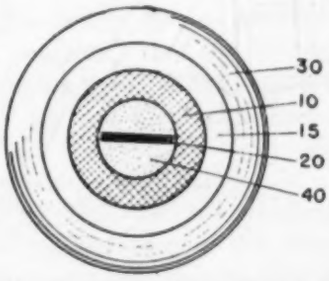

Fig. 6. Sectional views of self-supported flexible leads

an elongated core, [40], of circular cross section and made of elastic material such as neoprene. The flexible conductor, [10], is stranded around the core. The cored conductor is then soldered into the terminals and the outer flexible tubing is applied as indicated in Fig. 3. The results of the accelerated aging test are shown in Table I.

A number of advantages are derived from the concentric construction of this flexible lead, its essential characteristic being that the length of any element, except elastic parts, remains unchanged no matter how the flexible lead is bent in a longitudinal plane at right angles to the flat surfaces of the spring strip. (*A*) The flexible lead may be fabricated in straight lengths and supported in the form of an upright arch with its terminals either vertical or inclined toward one another at any desired angle, whereas a flexible lead having nonelastic elements of different bending radii must be fabricated and maintained with a predetermined shape of bend, i.e., with its terminals suitably spaced and parallel or inclined toward one another at a given angle. (*B*) The flexible lead is adapted to accommodate changes in the shape of bends and alignment such as occur in service. Lack of this property in other flexible leads referred to above introduced internal stresses which greatly reduced their useful life. (*C*) The construction of the flexible lead is such that none of its elements can become displaced. Deficiency in this respect has been a source of trouble with other water-cooled flexible leads as already related. (*D*) The electrical characteristics of the flexible conductor are improved as a result of its cored construction. This feature is of particular importance because of the magnitude of the currents carried (5–8 amp/1000 cir mils).

Flexible leads of the concentric design have been in service for several months. Their length of life in service is not yet known, but the results of the accelerated aging test indicate that they should operate two to three years without trouble. Failure on test resulted from fatiguing of the metal in the outer flexible tube with final cracking and leakage of the cooling water.

It seems that any further improvement in the life of these flexible leads will depend on improving the resistance to metal fatigue in the outer flexible tubing. Flexibility is obtained by means of annular or helical corrugations and by the use of metal having suitable thickness and resilience.

It is suggested that the resistance to fatigue of the metal used in the construction of flexible tubing of this type might be improved by the use of metal having two or more laminations separated from one another by a film or films of a suitable lubricant. An inner lamination of thinner metal would provide greater flexibility without loss of mechanical strength. The object is to obtain a tire-and-tube effect which will make the tubing still serviceable after cracks form in the outer lamination and until the equivalent of a "blow-out" occurs.

Flexible leads of the class referred to will operate without trouble for much longer periods if made with nonmetallic outer flexible tubing. Water-cooled flexible leads with neoprene outer tubes are being used. Unfortunately, nonmetallic tubes cannot continuously withstand the heat of flames or the radiant heat from furnace charges even when protected with asbestos fabric, as has been proven by trial.

It is found that if water-cooled flexible leads, with outer flexible tubing made of metal, are mounted in such a way that they may touch one another or other objects at a different electrical potential, they must be protected with insulation, such as that provided by asbestos sleeving, in order to prevent damage from arcing contacts.

The main sources of trouble with a self-supported flexible lead of the type described have been eliminated. A long-felt need for a water-cooled flexible lead suitable for low-frequency electric furnaces is therefore realized.

The previous portion of this paper dealt with the development, usage, characteristics, and advantages of self-supported, water-cooled furnace cables. The other aspects of these cables which are pertinent to this discussion are those of design and manufacture.

Design

It has been found that the requirements vary to such an extent that a new design must usually be prepared for each application. However, while the designs are all basically similar, there may be considerable difference in details.

The designer must know, or must determine from the operating engineers, certain limiting conditions under which the cables are to function. These include the electrode current, the vertical travel required, the spacing between the bus bar and the electrode terminals, and any details regarding clearance, etc., which may be applicable.

Usually, more than one cable per electrode is required to carry the current. A 3-phase 20,000 kva furnace may draw as much as 75,000 amp/electrode, and a multiple cable system is obviously required. The number of cables is often limited by certain features of furnace design. If so, a preliminary choice of conductor size is made, using current densities of from 5–8 amp/1000 circular mils of copper area. These correspond approximately to current densities of from 6000 to 10,000 amp/in.^{2} which are considerably higher than the average density of 1000 amp/in.^{2} often used in bus bar design. However, these current densities, or even higher ones, are satisfac-

tory as long as there is sufficient cooling water available to carry away the heat resulting from conductor losses, and as long as the cost of this heat loss can be tolerated. Based on these values of current density, the closest standard conductor size to that required is calculated.

The method of designing the conductor is not of particular interest here except to provide good flexibility. This can be achieved by using a large number of wires of annealed copper stranded together in the conventional manner to form a flexible conductor.

If the furnace is totally enclosed and near-normal ambient temperature conditions prevail, it is advantageous to use a reinforced neoprene hose which has almost unlimited ability to withstand flexing. Tests similar to those previously described were carried out on a cable having a hose of this type, and were concluded after 100,000 cycles of flexing without the cable having failed. The reinforcing is necessary to operate the hose under water pressure and must be nonmetallic to prevent the flow of induced currents which would overheat the reinforcing material and damage the hose.

If the cable is to be subjected to excessive heat or if there is danger of "blow-outs" of molten material from the furnace, a metallic hose is used. The type which has proved most successful is a seamless, flexible phosphor bronze hose. No wire braid reinforcement is necessary on this hose because the ends are restrained against longitudinal expansion and because the pressures used are such that the hose itself has ample strength against radial stresses.

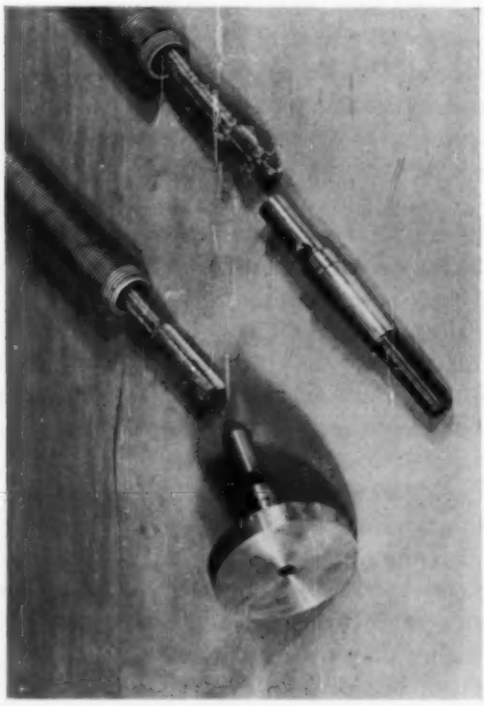

FIG. 7. Component parts of a self-supported, water-cooled cable with segmental conductor.

Knowing the conductor size, the designer can now calculate the approximate diameter of the terminals and decide on a size for the hose. This must be such that the hose can safely withstand continued flexing at the bending diameter corresponding to the required distance between the bus system and the electrode shoe. If this condition is not satisfied, the conductor size, and hence the number of cables required, must be revised.

The terminals are usually machined from copper rod and in general conform to the style shown in Fig. 3, although they may be modified somewhat to provide for different methods of making electrical and mechanical connections to the furnace. Clamps, tapered fittings, and solidly brazed connections are suitable connecting media. The cross-sectional area of the water passages, [6], [7], and [8], is made approximately equal to the area of the annular space, [15], between the conductor and hose. Only a moderate flow of water is required under a pressure of 30–60 psi. With current densities of the order previously mentioned, a water temperature rise of approximately 20° F above intake temperature is to be expected over the length of one cable.

The only main point left to consider is the length of the cable. This is dependent upon the vertical travel required. A simple arithmetical calculation involving the travel and mean bending diameter gives a minimum length for the hose. To this must be added a certain amount to insure that the hose is not subjected to bending at the point of connection to the terminals under extreme positions of travel. In practice, the length of a cable in its arched position is surprisingly short. The one with reinforced neoprene hose is 4 ft 9 in. in height. It has a 1,500,000 CM conductor, a 2⅜ in. ID hose, and is capable of a maximum safe travel of 4 ft 9 in.

MANUFACTURE

It is evident from the preceding discussion that there are considerable differences in the various cables and, since relatively small numbers of these cables are made, mass production or assembly line procedures are not usually possible. Therefore, it is necessary to design tools, jigs, and methods of assembly.

Fig. 7 depicts the component parts of a cable. The larger terminal is intended for bolting to the electrode shoe, and the smaller one is intended to be fastened into a tapered fitting on the bus bar system. The conductor in this case is of segmental construction, two flexible segments being laid on either side of the supporting strip of spring phosphor bronze and held in position by a bronze wire braid. One end of this conductor is shown cut and prepared for insertion in the terminal. The conductor is soldered into the terminals while fixed in a jig of the correct

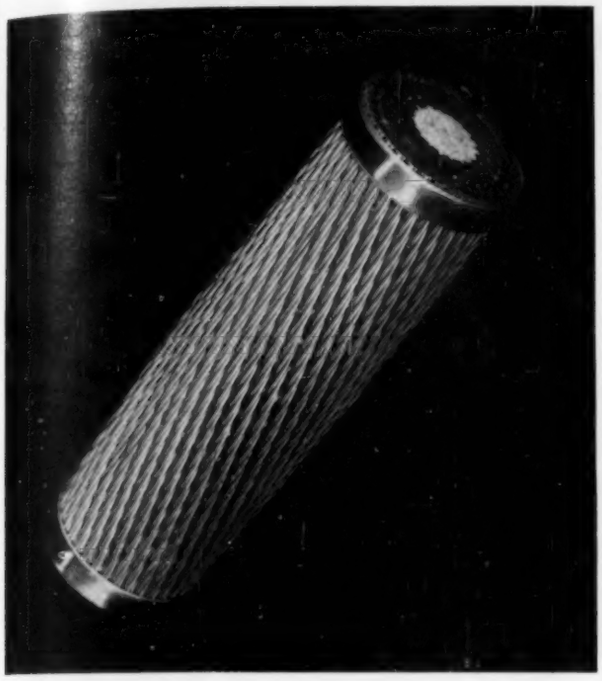

FIG. 8. 2,000,000 CM asbestos-cored cable

dimensions. For shipping, a clamp is fastened across the ends of the cable, between the two terminals, to maintain it at the proper bending diameter until installation is complete.

OTHER TYPES OF CABLES

Other types in use may be classified as: (*A*) water-cooled cables (*a*) supported by external means, and (*b*) unsupported; (*B*) bare cables (*a*) standard concentric stranded, and (*b*) special types, i.e., asbestos or spring cored.

A cable is said to be self-supporting if it can be installed in the form of an upright arch without external means of support. This is the type of cable which has already been described. When external support is required, it usually takes the form of a system of pulleys and counterweights. Some cables are not supported and hang in a loop between the bus bar and electrode. In general, water-cooled cables of these types are subject to much the same limitations regarding current carrying capacity length and bending diameters as are self-supported cables.

Bare flexible leads are commonly used for electric furnaces. Obviously, a proportionately greater cross-sectional area of copper is required than for water-cooled cables. Sufficient copper area must be provided to maintain a heat balance such that the cable is not damaged by excessive temperature rise. The cable is heated by resistance losses and by radiant heat from the furnace, and this heat must be dissipated into the air. Damage of the copper conductor from oxidation will result if its temperature exceeds 350°–400° F. There is thus a definite limit to the current which may be carried by a given cable under known conditions.

These cables may be of the usual concentric design, or they may be annular. The latter construction decreases alternating current losses and increases the surface area so that, for equivalent copper area, it has advantages over the standard concentric design. The annular construction is derived by stranding wires concentrically around a core of asbestos, a spiral spring, or similar material. Fig. 8 is a view of an asbestos-cored cable of 2,000,000 CM. It consists of 756 wires of #16 B&S annealed copper stranded around a ¾-in. asbestos rope. There is little advantage to be gained from using this construction in sizes less than 2,000,000 CM. Both standard concentric stranded and annular cables must be fitted into suitable terminals for attachment to the furnace.

CONCLUSION

In this paper the writers have attempted to present certain data which have been accumulated over the past 15 years in designing, manufacturing, and operating self-supported, water-cooled furnace cables. Several patents have been granted as a result of this work. The authors do not contend, nor has experience shown, that this type of cable is to be preferred above all others for every installation. However, it is suggested that under certain conditions self-supported, water-cooled cables can be used to advantage.

The following characteristics have been mentioned:

1. The power factor of the furnace can be improved by the use of short, interlaced multiple bus circuits combined with short flexible connections between the bus system and the electrodes. High effective electrode travel and low electrical reactance can be achieved by the use of arched cables.

2. Further reductions in reactance can be achieved by maintaining these flexible cables in an upright arch so that the length of all associated connections can be reduced to a minimum.

3. Advantages are derived from supporting the cables in this manner because the cable is farther away from the heat of the furnace.

4. The need for any auxiliary supporting apparatus is eliminated by the use of self-supporting cables.

5. More space is available for furnace operations because fewer cables are required and because more space is available directly over the "melt."

These advantages can only be fully realized when the cables can be operated with a reasonable freedom from maintenance and when the operating life is at least comparable to that of bare flexible leads.

Development has now progressed to such an extent that the authors believe these conditions can be fulfilled. Several such installations are in use in Canada and others are contemplated in the future in Canada, the United States, and Europe.

Acknowledgments

Credit is due to W. R. Tims, power cable design engineer of the Northern Electric Company, for originating the idea of placing the spring strip at the center of the flexible lead as shown in the 4-segment-conductor design, Figure 5. The authors also wish to acknowledge the cooperation of other associates in the development of flexible leads suitable for electric furnaces.

Any discussion of this paper will appear in a Discussion Section, to be published in the December 1954 issue of the JOURNAL.

Current Affairs

Society Spring Meeting in Chicago in May

Chicago's Michigan Avenue skyline

The Spring Meeting of the Society will be held May 2 to 6, 1954, at the LaSalle Hotel, Chicago. The 105th General Meeting will feature sessions of the Electric Insulation, Electronics, Industrial Electrolytic, and Theoretical Electrochemistry Divisions.

Reservations

The LaSalle Hotel is reserving a large block of rooms for Society members. If you plan to attend the meeting, you are urged to request accommodations directly from the hotel. Address: Room Reservations, LaSalle Hotel, Chicago 2, Illinois. It will be extremely helpful both to the hotel and to the local committee if you will specify that your reservation is for The Electrochemical Society meeting. As always, the earliest possible reservations are desired. Of course, reservation cards will be included when the Program Booklet is distributed, but advance reservations are strongly recommended.

Technical Meetings

In addition to the General Sessions of the four Divisions, special symposia and round tables will be held on Rare Metals, Molten Bath Electrolysis, Electric Insulation, Compression of Halogens, Luminescence, Instrumental Measurements, Screen Applications, and Semiconductors. Although plans are not yet complete, an exceedingly full technical program is anticipated, comprising about 20 half-day sessions.

Other Functions

In addition to the usual meetings of the Ways and Means Committee and the Board of Directors on Sunday, May 2, there will be a general Society luncheon and business meeting on Tuesday, and a meeting of the Local Section Advisory Committee. The Division Luncheons which are planned at present include Electric Insulation, Electronics, and Industrial Electrolytic.

An informal dinner and entertainment is planned for Monday evening,

O. W. Storey
Honorary Chairman

H. T. Francis
General Chairman

A. H. Roebuck
Registration

Clifford Hampel
Entertainment

and the President's Reception and Banquet for Tuesday evening. A Section Q session is scheduled for Wednesday.

A series of very interesting plant trips to some of Chicago's diverse industries is being scheduled, as well as varied activities for the ladies.

Members of the Chicago Section who are planning the Spring Meeting include Oliver W. Storey, Honorary Chairman; H. T. Francis, General Chairman; A. H. Roebuck, Registration; C. A. Hampel, Entertainment; Simon Gary, Finance; D. V. Louzos, Plant Trips; Ben Freeberg, Arrangements. Miss Marguerite Wall of Armour Research Foundation is in charge of the Ladies' Program. Acting as advisors are R. S. Modjeska and E. L. Koehler.

Notice to Members

Members of the Society *who are residents of New York City*, when ordering "Modern Electroplating," must make their checks payable to John Wiley & Sons, Inc., *for the sum* of $5.84 to cover the New York City sales tax. Orders for the volume, including the check, should be sent to Society Headquarters, 216 West 102nd St., New York 25, N. Y.

Members *outside of New York City* must make their checks payable to John Wiley & Sons, Inc., *for the sum of* $5.67. Send order for volume and check to Society Headquarters.

Dr. Prasad Visits Niagara Falls

The Niagara Falls Section was host to a distinguished visitor, Dr. B. K. R. Prasad of the Bombay Government, during his four-day visit to Niagara Falls. As the first Chairman of the India Section of The Electrochemical Society, Dr. Prasad was instrumental in the founding of that Section and has been an outstanding leader in India's electrical and electrochemical industry.

A series of tours to local industries and a dinner at the Red Coach Inn in Niagara Falls were arranged to enable Dr. Prasad to meet a number of the outstanding personalities in the electrochemical-metallurgical field in the Niagara area. The members of The Electrochemical Society present at the dinner were fortunate in hearing a first-hand account given by Dr. Prasad on the achievements, aims, and problems of India's industry.

C. E. E. R. I. in India

The Prime Minister of India laid the foundation stone of the Central Electronics Engineering Research Institute at Pilani, Rajasthan State, in September 1953. This will be the fourteenth institute in the chain of national laboratories set up by the Council of Scientific and Industrial Research all over India. Mr. G. D. Birla, the well-known Indian industrialist, has donated Rs.21 lakhs on behalf of the Birla Education Trust for its establishment. The Government of India has recognized the national importance of the proposed institute and made a provision of Rs.29 lakhs for it in the first five-year plan.

The object of the institute will be to undertake research and development on all aspects of electronics engineering. Special attention will be devoted to the utilization of indigenous raw materials in the manufacture of components, development and use of electronic circuits for industry, building of standard electronic instruments for test purposes, investigations on radar and other types of equipment, and applications of electronics in metallurgy. The institute will undertake projects sponsored by industry and close liaison will be maintained between the institute and industry.

The institute will consist of the following divisions: (*a*) electronic circuits, (*b*) electronic components, (*c*) electronic instruments, (*d*) acoustics-audio equipment, (*e*) ultra-high frequency and very-high frequency, (*f*) library and information, and (*g*) workshop.

T. L. Rama Char,
Regional Editor, India

Polyethylene Unit Being Built by Monsanto

Construction is now under way for the first polyethylene production plant of the Monsanto Chemical Company at Texas City, Texas. Located adjacent to Monsanto's existing Texas City plant, the new polyethylene unit, operated by the Plastics Division, is expected to produce commercial quantities of polyethylene starting the fourth quarter of 1954. Plans announced last March set initial annual capacity at about 66 million pounds, with a 50% increased capacity scheduled for 1957.

Burgess Chemical Changes Name to Cary Chemicals

Directors of the Burgess Chemical Company have announced a change in corporate name to Cary Chemicals, Inc., following a directors' meeting at which Kenneth B. Cary was elected president and George F. Blasius was made executive vice-president and general manager.

The laboratory and plant of Cary Chemicals, Inc., are located in Milltown, N. J., and the executive sales offices are in Paterson, N. J. Cary Chemicals, Inc., manufactures its own line of products, including vinyl compounds, reclaiming oils, pitch compounds, tall oil esters, stearine pitches, and other related materials, and also markets, as sales agents, other essential compounding ingredients for the rubber and plastics industries.

Zirconium Company Formed

Formation of the Zirconium Corporation of America has been announced by its president George R. Sylvester. The new company plans to manufacture various zirconium compounds, but will concentrate on production of zirconium oxide. The new, patented process to be used by the corporation was developed by Sylvester & Company of Cleveland under the direction of R. A. Schoenlaub. A pilot plant was run successfully for over a year, producing stabilized zirconium oxide. Present plans call for full-scale production at the new Solon, Ohio, plant in January.

Foxboro Establishes New Branch in Amarillo

The opening of a branch office in Amarillo, Texas, is announced by The Foxboro Company, of Foxboro, Mass., manufacturer of industrial instruments for the measurement and control of process variables. Located at 1117 La Paloma Street, the new branch was made necessary by expanded industrial activity in the region, particularly in the oil and gas, chemical and petrochemical industries.

MEETINGS OF OTHER ORGANIZATIONS

Chemical Institute of Canada, 6th Divisional Conference, Analytical Chemistry Division, Royal Hotel, Guelph, Ontario, February 18–19, 1954; 8th Divisional Conference, Protective Coatings Division, Montreal, February 25, 1954; 8th Divisional Conference, Protective Coatings Division, Toronto, February 26, 1954; 3rd Divisional Conference, Chemical Engineering Division, Montreal, March 1–2, 1954.

NATIONAL ASSOCIATION OF CORROSION ENGINEERS, Tenth Annual Conference and Exhibition, Kansas City, March 15–19, 1954.

FOURTH INTERNATIONAL CONFERENCE ON ELECTRODEPOSITION AND METAL FINISHING, sponsored by The International Council for Electrodeposition, Hotel Russell, London, April 21–24, 1954. Hothersall Memorial Lecture to Institute of Metal Finishing on Tuesday, April 20, by Dr. William Blum.

TENTH INTERNATIONAL PRINTING, MACHINERY AND ALLIED TRADES' EXHIBITION, The Grand and National Halls, Olympia, London, July 5–16, 1955.

Change of Address

The Columbia-Southern Chemical Corporation, subsidiary of Pittsburgh Plate Glass Company, has moved its General Offices from Fifth Avenue at Bellefield, Pittsburgh, to One Gateway Center, 420 Fort Duquesne Boulevard, Pittsburgh 22, Pa.

SECTION NEWS

Cleveland Section

The 182nd meeting of the Cleveland Section was held on Tuesday, December 8, 1953, at the Cleveland Engineering Society. Mr. Robert J. McKay, Society President, was speaker of the evening.

Prior to the meeting, dinner was served, after which Mr. McKay held an informal discussion on "Representation of Local Sections in the National Society."

As his lecture topic, Mr. McKay spoke on "Metal Ion and Oxygen Concentration Cells in Corrosion." He stressed the need for fundamental corrosion data in the electroplating field. He has had extensive experience in this field; he described some of his work including equipment, reactions involved, and conflicting theories on corrosive actions.

MERLE E. SIBERT, *Secretary*

Midland Section

Robert J. McKay, President of The Electrochemical Society and a Vice-President of the International Nickel Company, was the guest of honor at a dinner given by the local section on December 10 at the Midland Country Club.

Later he spoke on the subject of oxygen and metal ion corrosion before a joint meeting of the Midland Section of the Society and the Midland Section of the American Chemical Society. Mr. McKay gave a brief history of the theory of corrosion, and the problems involved in testing a satisfactory plate. He explained how corrosion may be measured by means of voltage and minute currents, and described the fundamental corrosion cell. He concluded that oxygen concentration is one of the biggest factors in metal corrosion.

M. P. NEIPERT, *Secretary-Treasurer*

Philadelphia Section

On Wednesday, December 16, 1953, the Executive Committee of the Philadelphia Section met at the Engineers' Club. After discussing current Section business, Dr. Eckfeldt read the following tribute to Dr. Lukens.

"Science is built in no small measure on the good faith, good will, and cooperation of the persons comprising the scientific community. Thus it is proper from time to time for the members of a scientific society to turn from scientific matters and give thought to their fellow members. The Electrochemical Society at large and our Philadelphia Section in particular have endeavored with success to foster a spirit of fellowship. To this end, the Executive Committee of the Philadelphia Section of The Electrochemical Society has traditionally held a meeting each year in the month of December, preceding the holiday season. This Christmas meeting always has a special significance to those persons in attendance who take this opportunity to express personally to each other their warmest and heartfelt wishes for a Merry Christmas and a Happy New Year.

"We of the Philadelphia Section have been fortunate in having members who, through their interest in the welfare and objectives of The Electrochemical Society, have unselfishly given their time and talents on behalf of this organization. It is fitting that an expression of appreciation should be given to such a person. Therefore, the members of the Executive Committee of the Philadelphia Section have designated that their meeting held on Wednesday the sixteenth day of December 1953 be set apart to honor and thank one of their beloved fellow members. Through his loyal and unceasing efforts for many years, Hiram Stanhope Lukens has given our Society and Section invaluable guidance, encouragement, and cooperation.

"Dr. Lukens has faithfully served our Section, as Secretary in 1930–31, as Chairman in 1931–32, and from 1931 down to the present time as an active member of the Philadelphia Executive Committee, throughout this whole period contributing his vital share in effective leadership and responsibility. All who enjoyed the national meetings of our Society sponsored by the Philadelphia Section, at Wernersville in 1940 and the meetings in Philadelphia in 1937, 1949, and 1952, are indebted in no small measure to the part played by Dr. Lukens in making these meetings successful.

"Dr. Lukens has rendered outstanding service to our Society at large. In 1934–35 he was President of our Society. He has served on various national committees including the Board of Directors and has carried the responsibility of chairmanship of several of these.

"Dr. Lukens has our sincere appreciation. We look forward to many more years of rewarding association with him in our activities. To him and his family at this Christmas season go our best wishes."

GEORGE W. BODAMER, *Secretary*

Washington-Baltimore Section

At the meeting of the Washington-Baltimore Section of The Electrochemical Society on November 19, 1953, Dr. C. G. Abbot of the Smithsonian Institution spoke on the subject, "Utilizing Solar Energy." Dr. Abbot reviewed the early work of the Smithsonian Institution in establishing stations in various locations throughout the world for daily measurements of solar radiation in order to determine the solar radiation constant which led to his interest in this field.

Dr. Abbot reviewed the early unsuccessful attempts to use lenses to power solar engines and subsequent attempts to use mirrors. Recently developed techniques in the preparation of mirror surfaces offer promise of more efficient machines. Dr. Abbot described an engine he has designed which can develop 2 hp using a spherical mirror ten feet in diameter. This mirror is approximately 25% efficient in the conversion of solar energy. However, spherical mirrors are difficult to fabricate and are expensive, so that the first practical engine probably will use a rectangular mirror which is less efficient and much cheaper. Dr. Abbot

expressed the opinion that, as our fuel supplies decrease in availability and increase in cost, solar engines will find increasing use in areas that experience sunny days most of the year.

Dr. William Blum, consultant and former Chief of the Electrodeposition Section, National Bureau of Standards, was the guest speaker at the December 17 meeting of the Washington-Baltimore Section.

Dr. Blum has recently returned from Australia where he spent several months as a guest of the three Australian Branches of the American Electroplaters' Society. During his trip, he visited a number of research laboratories and industrial concerns employing electrochemical processes. Dr. Blum's account of his experiences, which was accompanied by numerous slides, was extremely interesting.

FIELDING OGBURN, *Secretary*

NEW MEMBERS

In December 1953, the following were elected to membership in The Electrochemical Society:

Active Members

SIDNEY M. BLITZER, Ethyl Corporation, mailing add: 2826 Terrace Avenue, Baton Rouge, La. (Industrial Electrolytic and Theoretical Electrochemistry)

WAYNE M. GAUNTT, Reynolds Metal Co., 2000 S. Ninth St., Louisville, Ky. (Corrosion, Electrodeposition, Electronics, Electro-organic, and Theoretical Electrochemistry.)

ROBERT A. GILBERT, Battelle Memorial Institute, mailing add: 921 Oxley Rd., Columbus 12, Ohio (Electrothermic)

ALBERT E. HENDRICKSON, Sylvania Electric Products Inc., mailing add: 75-14 Vleigh Pl., Flushing, N. Y. (Electronics)

NORBERT IBL, Swiss Federal Institute of Technology, mailing add: Steinwiesstr. 52, Zurich 32, Switzerland (Theoretical Electrochemistry)

JEROME KRUGER, Naval Research Laboratory, mailing add: 8101 14th Avenue, Hyattsville, Md. (Corrosion)

MANLEY W. MALLETT, Battelle Memorial Institute, mailing add: 1285 Arlington Ave., Columbus, Ohio (Corrosion and Electrothermic)

RICHARD W. MOONEY, Sylvania Electric Products Inc., 60 Boston St., Salem, Mass. (Electronics)

MARGIE M. NICHOLSON, Humble Oil and Refining Co., mailing add: 120 Marion Ave., Baytown, Texas (Theoretical Electrochemistry)

FRANK P. SCHIRO, Signal Corps, Ft. Monmouth, mailing add: 14 Queens Dr., Little Silver, N. J. (Battery)

DONALD M. SOWARDS, University of Texas, mailing add: 2917 West Ave., Austin, Texas (Theoretical Electrochemistry)

PERSONALS

WILLIAM N. DUNLAP has accepted the position as assistant project engineer with the Friez Instrument Division, Bendix Aviation Corporation, Baltimore, Md. He was formerly supervisor of Plating Laboratory, Chrysler Corporation, New Orleans, La.

W. L. HADEN, JR., research chemist, Attapulgus Minerals and Chemicals Corporation, Camden, N. J., has been promoted to research supervisor of the company.

TADAYUKI NAKAYAMA, previously with the Scientific Research Institute, Tokyo, Japan, is now associated with Castings Research Laboratory in Tokyo.

FERNAND PORTAIL, Compagnie Industrielle des Piles Electriques, France, has been awarded the Gaston Plante Medal from the Société des Electriciens.

HOWARD A. ACHESON was recently re-elected president and chairman of the board of Acheson Industries, Inc.

BOOK REVIEWS

ION EXCHANGERS IN ANALYTICAL CHEMISTRY by Olof Samuelson. Published by John Wiley & Sons, Inc., New York, 1953. XVIII plus 291 pages, $6.50.

"Ion Exchangers in Analytical Chemistry" represents the first successful effort by any author to provide the analytical chemist with a practical working introduction to the field of ion exchange. The book is not intended as a comprehensive source of references but rather as an indication of the possibilities of ion exchange methods as analytical tools.

The first part of the book consists of an explanation of ion exchange phenomena. Theoretical discussion is kept to a minimum with the emphasis being placed on properties of ion exchangers, experimentally determined principles of ion exchange, and empirical equations governing equilibria and kinetics. Operating techniques of ion exchange procedures are discussed from a practical standpoint in the second section. The final (and major) portion of the book illustrates the applications of these techniques in inorganic, organic, and biochemical analysis. The many detailed procedures given in this section should be of help to the analytical chemist who desires to apply ion exchange methods to his own particular problems.

Because of the wide range of subject matter covered, this work will be of general interest to analytical chemists in all fields. The book is very readable and, coming as it does from one of the recognized experts in this new field, should be authoritative.

THOMAS C. LOOMIS

INTRODUCTION TO SOLID STATE PHYSICS by Charles Kittel. Published by John Wiley & Sons, Inc., New York, 1953. 396 pages, $7.00.

In the last decade the number of physicists working in the field of solid state has expanded greatly. To a large extent this increase has come about because of the growth of industrial laboratories. There has been no corresponding expansion of university instruction in the physics of solids. One of the reasons for this state of affairs may very well be the difficulty of organizing our information in a form suitable for classroom instruction. The "Introduction to Solid State Physics" by Charles Kittel recognizes this difficulty and sets out to overcome it. In accordance with this purpose, it contains neither a logical buildup of the theory of solids from first principles, nor a comprehensive review of all the accumulated information. Instead, it treats certain limited topics which have been handled successfully by experimental methods and for which the results can be understood through simple (although not always rigorous) reasoning. Since it has proved almost impossible to design a course around the two other viewpoints above, this new departure is to be commended.

The book starts out with the topics of ionic crystals and lattice vibrations which are of outstanding importance because of their historical impact upon physics as a whole. The central part deals with dielectric and magnetic phenomena. The book then passes to the theory of free electrons, band theory of metals and semiconductors, and finally

to theories of crystal imperfections. In most of these sections the aim of developing a simple exposition suitable for classroom use is brilliantly realized, so much so that a word of caution may be in order here and there about the rigor and completeness of the reasoning presented. One such case is, for instance, the theory of order-disorder transformations which is given, justifiably, a very simple form; however, even the references which are supposed to review the field and present "a careful discussion" of slurred-over points share this simplicity so that the reader does not even get an inkling of the intensive thinking which has been going on in this field. Another case in point arises in the theory of lattice vibrations which Van Hove has advanced beyond the position indicated either by the book itself or the references quoted. The opposite type of difficulty, namely that of a reasoning too obscure for classroom exposition arises seldom; one such case is, perhaps, the theory of metallic conduction, which is a notoriously recalcitrant field from the expository viewpoint.

In conclusion, it may be said that Professor Kittel has created an excellent introductory textbook in a field where this type of exposition was never tried before. It is to be hoped that the student for whom it is designed will like it, and get from it a sympathetic viewpoint toward physical reasoning in the study of solids.

G. H. Wannier

Chemical Constitution by J. A. A. Ketelaar; translated by L. C. Jackson. Elsevier Publishing Company, Houston, Texas, 1953. VIII + 398 pages, $6.50.

"Chemical Constitution" subtitled "An Introduction to the Theory of the Chemical Bond" is intended by its author, Dr. J. A. A. Ketelaar, to serve as "... a complement to the usual textbooks of inorganic and organic chemistry which will enable [the chemist] to build up the great mass of data into a coherent body." This first English edition is a translation from the Dutch by Dr. L. C. Jackson.

The book is divided into four major parts concerned with the ionic bond, the atomic (covalent) bond, the metallic bond, and van der Waals bonding, in that order, and, although each bond type is considered separately, the essential similarities are stressed. The author strives to relate physical and chemical properties to molecular structure and is notably successful in this endeavor. The presentation is systematic and, where possible, general principles or rules are stated and illustrated by numerous examples. Recent experimental data are included in many sections of the text.

After a short introduction, in which the periodic table and the wave properties of electrons are discussed, the ionic bond is considered in detail. Crystal structure, ionic radii, and lattice energies are taken up generally, and the conclusions derived are applied to specific systems. In addition to simple ionic compounds, complex systems are treated at some length. The sections on polynuclear complexes and glasses contain good descriptive material but would be more readily comprehended if more structure diagrams were included. Properties such as electrolytic dissociation, acid-base strength, volatility, hardness, and solubility are discussed in relation to the ionic bond.

Discussion of the atomic bond is prefaced by a brief review of quantum mechanical principles with the hydrogen atom, the hydrogen molecule ion, and the hydrogen molecule receiving most emphasis. The resonance concept is given a lucid treatment. Hybridization is presented qualitatively and a large number of examples are given with reference to directional characteristics and the magnetic criterion of bond type. Double and triple bonds, the concept of pi-electrons, and conjugation are introduced qualitatively. A section is included on the theory of color, followed by a review of approximate methods of calculation used in quantum theoretical chemistry.

The metallic bond receives brief treatment from the point of view of quantum mechanics and the band model. Semiconductors and alloys are discussed as is Pauling's theory of metals. An interesting section on the factors responsible for mechanical properties of metals is included.

The final chapter is an excellent treatment of van der Waals forces and their influence on physical and chemical properties. Use of van der Waals equation of state in theoretical considerations regarding boiling points and solubilities is given in considerable detail. The final section is a good summary on hydrogen bonds.

The attention of the author to the dependence of physical and chemical properties on molecular structure is outstanding and makes this text a worth-while contribution. It is felt, however, that the mathematical parts of the quantum mechanical sections will not be readily comprehended by persons not previously trained in quantum theory.

The text is relatively free of typographical errors and the translation is adequate. Insufficient references limit the utility of the book for reference purposes.

David W. McCall

RECENT PATENTS

Selected for electrochemists by Fred. W. Dodson, Chairman of the Patent Committee, from the Official Gazette.

November 3, 1953

Faust, C. L., and Hespenheide, W. G., 2,658,032, Electrodeposition of Bright Copper-Tin Alloy

Ferris, D. E., 2,658,033, Electrolytic Method and Apparatus for Sterilizing Water

La Burthe, P. H., 2,658,093, Manufacture of Glass

Nonken, G. C., 2,658,094, Combined Electrode and Skimmer for Electric Glass Melting Furnaces

Arbeit, P., Dubois, R., and Lambert, R. E., 2,658,095, Process and Apparatus for Making Glass

Peyches, I., 2,658,096, Apparatus for the Manufacture of Multicellular Glass

Orsino, J. A., 2,658,097, Manufacture of Positive Plates for Lead Storage Batteries

Coleman, J. J., and Kurlandsky, S., 2,658,098, Dry Battery with Conductive Tape Intercell Connections

Basset, L. P., 2,658,099, Microporous Carbon and Graphite Articles, Including Impregnated Battery Electrodes and Methods of Making the Same

Kendall, T. L., 2,658,100, Vent Cap

November 10, 1953

Du Rose, A. H., and Little, J. D., 2,658,266, Laminated Coating

Talmey, P., and Crehan, W. J., 2,658,839, Process of Chemical Nickel Plating

Gutzeit, G., and Krieg, A., 2,658,841, Process of Chemical Nickel Plating and Bath Therefor

Gutzeit, G., and Ramirez, E. J., 2,658,842, Process of Chemical Nickel Plating and Bath Therefor

Society Prizes and Awards

The Edward Goodrich Acheson Medal and Prize

The Edward Goodrich Acheson Gold Medal and $1,000 Prize were founded by Dr. Acheson in August 1928.

The award is made once every two years (first award at the Fall Meeting, 1929) to the person who shall have made a distinguished "contribution to the advancement of any of the objects, purposes, or activities . . . of the Society. Such contribution may consist of but shall not be limited to (*a*) a discovery pertaining to electrochemistry, electrometallurgy, or electrothermics, (*b*) an invention of a plan, process or device, or research evidence by a paper embodying information, useful, valuable, or significant in the theory or practice of electrochemistry, electrometallurgy, or electrothermics, and/or (*c*) distinguished services rendered to the Society or its successor."

The award is made without distinction on account of sex, citizenship, race, or residence. See *Trans. Electrochem. Soc.*, **54,** 6 (1928).

The Palladium Medal

The Palladium Medal of The Electrochemical Society was founded in 1950. The source of funds for the establishment of the medal is the royalties derived from sales of the *Corrosion Handbook* which was sponsored and largely written by members active in the Corrosion Division of the Society. Dr. H. H. Uhlig served as Editor-in-Chief.

The award of the medal is to be made every two years to a scientist, in recognition of original and outstanding contributions to the knowledge of corrosion in one or more of the following fields: the theory of corrosion or corrosion control, electrode potentials, properties of electrolytes, electrode reactions, and the surface properties of metals. The jury for the selection of the medalist is appointed by the Board of Directors of the Society and consists of three members, including one member from the Corrosion Division and one from the Theoretical Division, both of whom are active in their respective fields. See *J. Electrochem. Soc.*, **98,** 95*C* (1951).

The Joseph W. Richards Memorial Lectureship

Dr. Joseph William Richards was one of the founders of The Electrochemical Society, and its first President. He was Secretary and Editor of the Society's TRANSACTIONS from 1904 to 1921. His very active and untiring interest in the Society and in the science and art of electrochemistry reflected itself in the rapid growth of the Society and of the electrochemical industry throughout the world. From the very start, Dr. Richards fostered the international spirit.

The Joseph W. Richards Memorial Lectureship was established in 1929 by a group of friends and admirers of Dr. Richards. The interest of the fund is used to meet the expenses incurred by inviting and entertaining distinguished scientists. See *Trans. Electrochem. Soc.*, **57,** 30 (1930).

The Electrochemical Society Prize to Young Authors

An annual prize of one hundred dollars was established by the Board of Directors in July 1928. The prize is awarded to the author of the best paper printed in the yearly volume of the JOURNAL of the Society. The judges to pass upon the merits of the paper are the Chairman of the Publication Committee, the Secretary of the Society, and three members of the Society, and two alternates, selected by the Chairman of the Publication Committee, the Committee being at liberty to invite the opinion of members not on the Committee.

The prize is open to students and graduates, under thirty-one years of age, of any technical school, college, or university, no matter where located. See *Trans. Electrochem. Soc.*, **55,** 22 (1929); **92,** viii (1947).

Francis Mills Turner Award, Sponsored by the Reinhold Publishing Corporation

For several years, Francis Mills Turner personally offered an annual prize consisting of $50.00 worth of scientific and technical books published by the Reinhold Publishing Corpora-

Honorary Members of the Society

CHARLES F. CHANDLER,* New York, N. Y.	Volume 35 (1919)
EDGAR F. SMITH,* Philadelphia, Pa.	Volume 35 (1919)
CARL HERING,* Philadelphia, Pa.	Volume 41 (1922)
EDWARD G. ACHESON,* Niagara Falls, N. Y.	Volume 43 (1923)
WILDER D. BANCROFT,* Ithaca, N. Y.	Volume 47 (1925)
EDWARD WESTON,* Montclair, N. J.	Volume 50 (1926)
THOMAS A. EDISON,* Orange, N. J.	Volume 54 (1928)
W. LASH MILLER,* Toronto, Canada	Volume 55 (1929)
EDWARD DEAN ADAMS,* New York, N. Y.	Volume 57 (1930)
CHARLES F. BURGESS,* Chicago, Ill.	Volume 62 (1932)
FREDERICK MARK BECKET,* New York, N. Y.	Volume 66 (1934)
L. H. BAEKELAND,* New York, N. Y.	Volume 69 (1936)
ROBERT A. WITHERSPOON, Montreal, Canada	Volume 78 (1940)
ARCHER E. WHEELER, New York, N. Y.	Volume 80 (1941)
W. R. WHITNEY, Schenectady, N. Y.	Volume 85 (1944)
PAUL J. KRUESI, Chattanooga, Tenn.	Volume 85 (1944)
COLIN G. FINK,* New York, N. Y.	Volume 89 (1946)
JOHN W. MARDEN, Bloomfield, N. J.	Volume 91 (1947)
WILLIAM BLUM, Washington, D. C.	Volume 100 (1953)

* Deceased

tion. At the time of his demise, the Reinhold Publishing Corporation established the "Francis Mills Turner Memorial Award, Sponsored by the Reinhold Publishing Corporation," consisting of $100.00 worth of scientific and technical books to be given each year to an author under 31 years of age. This revision was gratefully accepted by the Board of Directors at the Society convention held in Philadelphia, May 4 to 8, 1952. See *J. Electrochem. Soc.*, **99**, 162*C* (1952).

Consolidated Fellowship Fund

Due to the deterioration of the Weston Fellowship funds, the Board of Directors on October 26, 1952 established a Consolidated Fellowship Fund from the accumulated earnings of the Weston Fellowship Fund, the entire Roeber Research Fund, the excess earnings of the Acheson Fund, and the $1000 returned by John W. Marden (Acheson Award) at the Montreal Meeting. This fund will be accumulated until such time as the Society has available sufficient yearly income from this source to justify offering a fellowship, at which time the Society again will be in a position to sponsor graduate studies in electrochemistry.

Former recipients of the Acheson Medal and Weston Fellowship are listed below.

Prize Essay Contest

The Electrochemical Society sponsors an essay contest, which is open to undergraduate and graduate students, on a selected subject. Two prizes are awarded for the two best essays submitted: first prize is $100, plus a one-year subscription to the JOURNAL; second prize is $50, plus a one-year subscription to the JOURNAL.

Prizes for the contest are financed by royalties from the sale of the "Corrosion Handbook," a widely used technical publication sponsored by the Corrosion Division and published by John Wiley & Sons, Inc., in 1948. See *J. Electrochem. Soc.*, **100**, 68*C*, 282*C* (1953).

Winners of Society Prizes and Awards

Acheson Medalists

EDWARD G. ACHESON*—Artificial Graphite and Carborundum—**56,** 7 (1929).

EDWIN F. NORTHRUP*—Induction Furnaces—**60,** 8 (1931).

COLIN G. FINK*—Electrochemistry—**64,** 2 (1933).

FRANK J. TONE*—Electrothermics—**68,** 2, 8 (1935).

FREDERICK M. BECKET*—Electrothermics—**72,** 3 (1937).

FRANCIS C. FRARY—Electrometallurgy—**76,** 4 (1939).

CHARLES F. BURGESS*—Electrochemistry—**82,** 3 (1942).

WILLIAM BLUM—Electrodeposition—**86,** 4 (1944).

H. JERMAIN CREIGHTON—Electro-Organic Chemistry—**90,** 5 (1946).

DUNCAN A. MACINNES—Electrochemistry—**94,** 4*P* (1948).

GEORGE W. VINAL—Batteries—**97,** 231*C* (1950); **98,** 11*C* (1951).

JOHN W. MARDEN—Electronics—**100,** 37*C* (1953).

Weston Fellowship Holders

EDWARD B. SANIGAR—"The Titration of Potassium Cyanide and of Free Cyanide in Silver-Plating Solutions by Means of Silver Nitrate"—**58,** 435 (1930); "Electrodeposition of Silver from Sulfate, Nitrate, Fluoborate and Fluoride Solutions"—**59,** 307 (1931).

KARL SOLLNER—"An Experimental Study of Negative Osmosis. Part I"; "Experimental Verification of a New Theory Concerning the Mechanism of Anomalous Osmosis. Part II"—**61,** 477, 487 (1932).

MARLIN E. FOGLE—"A Study of Cuprous Oxide Solid Photoelectric Cells"—**66,** 271 (1934).

ROBERT D. BLUE—"Electrodeposition of Aluminum from Non-Aqueous Solutions"—**65,** 339 (1934).

PIERRE A. JACQUET—"Effect of Colloids on Electrodeposition"—**65,** 21 (1934).

MYRON A. COLER—"Electrolytic Processes in the Magnetic Field"—**72,** 247 (1937).

HENRY B. LINFORD—"The Effect of the Speed of Rotation on the Electrode Potentials of Copper and Zinc"—**72,** 461 (1937).

GARTH L. PUTNAM—**71,** 26 (1937).

VITTORIO DE NORA—**73,** 39 (1938).

WALDEMAR P. RUEMMLER—**75,** 52 (1939); **77,** 50 (1940).

RODNEY E. BLACK—**79,** 44 (1941).

WILLIAM E. ROAKE—**81,** 46 (1942).

ROBERT D. MISCH—**93,** 14*P* (1948).

MASSOUD T. SIMNAD—**94,** 3*N* (1948)†; **97,** 161*C* (1950).

Joseph W. Richards Memorial Lecturers

JOHN A. MATHEWS,* Vice-President and Director of Research, Crucible Steel Company, New York, N. Y. "The Electric Furnace and the Alloy Age," **61,** 143 (1932).

R. S. HUTTON, Goldsmiths' Professor of Metallurgy, University of Cambridge, England. "Faraday and His Electrochemical Researches," **64,** 13 (1933).

W. S. LANDIS,* Vice-President and Director, American Cyanamid Company, New York, N. Y. "Joseph W. Richards, The Teacher—The Industry," **66,** 6 (1934).

KARL K. DARROW, Physicist, Bell Telephone Laboratories, New York, N. Y. "Electricity in Gases," **69,** 67 (1936).

CHARLES H. HERTY,* Director, Herty Foundation Laboratory, Savannah, Ga. "The Utilization of Southern Pine," **73,** 50 (1938).

BRADLEY STOUGHTON, Dean of Engineering, Lehigh University, Bethlehem, Pa. "Modern Marvels of Electrometallurgy," **76,** 29 (1939).

VLADIMIR K. ZWORYKIN, Associate Director of RCA Research Laboratories, Camden, N. J. "The Electron Microscope," **80,** 14 (1941).

B. D. SAKLATWALLA,* Metallurgical Consultant, Pittsburgh, Pa. "Thermal Reactions in Ferro-Alloy Metallurgy, the Basis of Alloy Steel Development," **84,** 13 (1943).

STEWART J. LLOYD, Professor of Chemical Engineering, University of Alabama, University, Ala. "Freedom in Science," **89,** 9 (1946).

OLIVER W. STOREY, Consultant, Burgess Battery Company, Chicago, Ill. "Research in Industry—Is Government Antagonistic to It?" **96,** 3*P* (1949); **97,** 9*C* (1950).

* Deceased.

† *J. Electrochem. Soc.*

* Deceased.

J. O'M. Bockris, Lecturer, Department of Inorganic and Physical Chemistry, Imperial College of Science and Technology, London University, London, England. "Overpotential," **98,** 153*C* (1951).

Palladium Medalists

Carl Wagner, Department of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass. "The Electrochemistry of Ionic Crystals," **99,** 346*C* (1952).

Nathaniel Howell Furman, Chairman, Department of Chemistry, Princeton University, Princeton, N. J. "Coulometry—Related Phenomena of Electrolysis and Current-Sweep Polarography," **101,** 19*C* (1954).

Winners of Young Authors' Prize

William C. Gardiner—"Hydrolysis of Mercurous Sulfate by Cadmium Sulfate Solution in the Weston Normal Cell"; "Oxidation of the Depolarizer in Preparing Standard Cells"; "Crystalline Mercurous Sulfate and the Weston Normal Cell"—**56,** 111, (1929).

Dwight K. Alpern—"Engineering Development of Photovoltaic Cells"—**58,** 275 (1930).

Frank L. Jones—"Electrodeposition of Tungsten from Aqueous Solutions"—**59,** 461 (1931).

F. W. Godsey, Jr.—"Alternating Current Capacities of Electrolytic Condensers"; and "Potential Gradients in Anodic Films"—**61,** 515, 549 (1932).

B. L. Bailey—"Hardness Values for Electrochemical Products"—**63,** 369 (1933).

Joseph R. Heard, Jr.—"Electro-Organic Oxidations in Concentrated Aqueous Organic Salt Solutions"—**65,** 301 (1934).

Upton B. Thomas, Jr.—"Electrochemical Behavior of Lead, Lead-Antimony and Lead-Calcium Alloys in Storage Cells"—**68,** 293 (1935).

W. A. Johnson—"Studies of Overvoltage: Effect of Fusion of the Cathode and Effect of Temperature on Gas Polarization"—**70,** 259 (1936).

R. Spencer Soanes—"Potential Distribution in High Current Carbon Arcs in Air"—**72,** 281 (1937).

N. B. Nichols—"The Cathode Ray Oscillograph Applied to the Dropping Mercury Electrode"—**73,** 193 (1938).

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BRANCH OFFICES IN: Newark, N. J., Syracuse, N. Y., Cleveland, O., Cambridge, Mass., Philadelphia, Penn., St. Louis, Mo., Chicago, Ill., Dallas, Tex., Los Angeles, Cal.

G. A. Moore—"Comportment of Palladium-Hydrogen System toward Alternating Electric Current"—**75,** 2[illegible] (1939).

J. S. Mackay—"Photoelectric Cell Sensitive to Long Wave Length Radiation: The Bismuth Sulfide Cell"—**77,** 299 (1940).

Edward Adler—"Photovoltaic Effect"; "Semi-Conductor Photocells and Rectifiers"—**79,** 367, 377 (1941).

Sidney Speil—"Electrophoretic Dewatering of Clay"—**81,** 119 (1942).

Walter G. Berl—"A Reversible Oxygen Electrode"—**83,** 253 (1943).

John P. Coyle—"The Extraction of Indium from Complex Lead-Tin Alloys"—**85,** 223 (1944).

Austin E. Hardy—"The Photoconductivity of Zinc-Cadmium Sulfide as Measured with the Cathode-Ray Oscillograph"—**87,** 355 (1945).

Norman A. Nielsen—"Passivation of Stainless Steels"—**89,** 167 (1946).

Henry Leidheiser, Jr.—"The Influence of Crystal Face on the Electrochemical Properties of a Single Crystal of Copper"—**91,** 95 (1947).

Michael A. Streicher—"The Dissolution of Aluminum in Sodium Hydroxide Solutions"—**93,** 285 (1948).

J. C. Griess, Jr.—"The Electrodeposition Behavior of Traces of Silver"—**95,** 33 (1949).

George W. Murphy—"The Separation of Simple Electrolytes in Solution by an Electro-Gravitational Method"—**97,** 405 (1950).

John T. Byrne—"Critical Interpretation of Electrodeposition Studies Involving Traces of Elements"—**98,** 457 (1951).

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Through error, the incorrect price for "Modern Electroplating" was given in the John Wiley and Sons, Inc. ad which appeared in the January 1954 Journal. The correct price of "Modern Electroplating" is $8.50.

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